UNIVERSITY OF ALBERTA

THE RELATIONSHIP OF SELECTED ANTHROPOMETRICAL AND PHYSIOLOGICAL VARIABLES TO THE BALKE TREADMILL TEST AND A TERMINAL STEP TEST AND TEST INTERRELATIONSHIP

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

FACULTY OF PHYSICAL EDUCATION

by

ANDREW PETER BAKOGEORGE

EDMONTON, ALBERTA

JULY, 1964.

APPROVAL SHEET

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Relationship of Selected Anthropometrical and Physiological Variables to the Balke Treadmill Test and a Terminal Step Test, and Test Interrelationship" submitted by Andrew P. Bakogeorge in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this study was to determine the relationship of selected anthropometrical and physiological variables to performance in the Balke Treadmill and the Terminal Step tests and the relationship of specific Terminal Step test parameters to Balke Treadmill test performance time. Subsidiary problems investigated were the validation of the regression equation procured for Balke Treadmill test performance time and the construction of a standard score normative chart for performance times in the two work capacity tests.

Ninety male students at the University of Alberta served as subjects in this experiment. Observations collected on the initial 45 subjects were age, weight, height, leg length, leg length - height ratio, bilateral strength of the plantar flexors, knee and hip extensors, their combined strength, treadmill and step test external work, treadmill and step test performance time and pre -, post - and exercise heart rates for the two work capacity tests. Based on this data, the relationships of the problem were analyzed by simple correlations and stepwise regression, respectively. An additional 45 subjects, tested for performance in the step and treadmill tests, were utilized in an attempt to validate the derived regression equation for performance time in the treadmill test. The relationship between step test and treadmill test performance time was also determined.

Performance times in the two work capacity tests, for the ninety subjects, were employed in the establishment of the normative chart.

Within the limitations of the study, it was concluded that there was a general futility in trying to obtain significant relationships between isolated linear or volumetric measurements and performance time in the Balke Treadmill or Terminal Step tests. Post-exercise heart rates and strength measures were not significantly correlated with performance time in either test. Pre-exercise heart rates tended to reveal significant relationships with treadmill

and step test performance time but these relationships were too low to be of any consequence. There were significant relationships between exercise heart rates and performance time in the treadmill and step tests - the magnitude of these relationships increased as the time, at which the exercise heart rate was taken, increased. Spurious correlation coefficients were obtained between treadmill and step test external work and their respective performance times. There were no significant relationships between step test post-exercise heart rates and treadmill performance time. The relationships between step test exercise heart rates and treadmill performance time, and between step test external work and treadmill performance time, resulted in produced correlation coefficients. A statistically significant relationship was found between performance times in the step and treadmill tests ($r = 0.776$ - sample one and $r = 0.892$ - sample two).

Terminal Step test performance time was found to account for 60.24 percent of the total interpersonal variance in Balke Treadmill test performance time, and the inclusion of other step test parameters were not considered to be of statistical importance. The derived regression equation predicted treadmill performance time for the validation sample well within two standard errors of estimate but was deemed to be of limited value.

The normative table for performance times in the Balke Treadmill and Terminal Step tests was regarded as only applicable to the population from which data to derive the table was procured.

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation and gratitude to his committee members, Dr. M. L. Howell, D. S. Rule and Dr. R. B. J. Macnab for their guidance and constructive criticism throughout the writing of this thesis.

Appreciation must also be expressed to Dr. K. M. Smilie for his assistance and direction in the use of the University of Alberta Computing Centre.

Special gratitude is extended to my wife, Marion, for her patience and assistance through typing the entire manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction. During the Second World War, the concern over the level of physical fitness of the North American people again became evident. As a result, a variety of tests were devised to measure this nebulous entity - physical fitness.

One such test, stemming from experimental research at the Harvard Fatique Laboratory, was the Harvard Step test (1, 2, 3). This was a bench stepping test designed to measure the functional status of the body and its ability to perform and recover from strenuous work. It purported to classify adult men into levels of fitness by means of a physical efficiency index based upon the duration of exercise and the heart rate recovery from exercise.

During and subsequent to the war years, this test, synonymously termed the Brouha Step test, has been frequently employed to measure cardiovascular fitness (4, 5, 6, 7), the effects of physical conditioning and training programs on cardiovascular fitness (8, 9), and as an item in a battery of tests measuring physical fitness (10). Moreover, modifications in test duration, in stepping cadence and/or in bench stepping height have rendered the test applicable to boys (11), to older men and patients (12), to young women (13, 14, 15) and to girls (16, 17).

The original form of the Harvard Step test and its physical efficiency index have been criticized for several reasons:

1. a bench height of twenty inches favours the tall light person and handicaps the short stout person (15, 18, 19, 20, 21, 22),

2. the duration of the test is too short to allow a clear cut differentiation between levels of physical fitness (23),

3. the test results in muscle soreness of the legs even though a

natural stepping skill is employed (5, 15, 21),

4. correlation coefficients between the physical efficiency index (recovery index) of this test and the scores of other functional physical fitness tests are very low, indicating that these tests do not purport to measure the same component of fitness or do measure the same component but not to the same extent (24, 25, 26) and

5. the use of the recovery heart rate in the physical efficiency index does not appear to be a valid means of assessing an individual's level of cardiovascular fitness (20, 27, 28, 29).

In spite of these criticisms, the utilitarian aspects of a form of the Harvard Step test, in which the test is terminated at a specific heart rate, might prove extremely valuable in assessing an individual's level of functional physical fitness.

Balke (30:74) has stated, ". . . physical fitness depends on the individual's biodynamic potential which is composed of his functional and his metabolic potential." In attempting to assess this biodynamic potential, Balke has developed an objective testing procedure, proven to be successful for a number of years, to determine man's functional potential - his aerobic capacity for maximum functional demands. The form of exercise used was walking a motor driven treadmill at a constant speed of 91 metres per minute while the slope of the treadmill was increased one percent of the belt distance travel per minute at the end of the first minute and each minute thereafter. Performance time was considered to be the length of time taken for the individual's heart rate to reach 180 beats per minute.

If performance in a form of the Harvard Step test were terminated at a heart rate of 180 beats per minute and if certain specific parameters of this form of test were correlated in a statistically significant manner with performance time in the Balke Treadmill test, this form of the Harvard

Step test might be considered a simple, more economical method of determining man's functional potential.

The Problem. The purpose of this study is twofold:

1. to investigate the relationship of selected anthropometrical and physiological variables to performance in the Balke Treadmill test and in a Terminal Step test, and

2. to determine the relationship of specific parameters of the Terminal Step test to performance time in the Balke Treadmill test.

Subsidiary Problems. In direct relation to the purpose of this study, there are two subsidiary problems:

1. to determine the validity of the multiple regression equation established for performance time in the Balke Treadmill test utilizing a sample not previously selected but drawn from a similar population, and

2. to construct a normative table in standard score form for the performance times of University of Alberta freshmen in the Balke Treadmill test and in the Terminal Step test.

Null Hypothesis. The following null hypothesis will be investigated: that there is no relationship of the selected anthropometrical variables of weight, height, leg length and leg length/height ratio, and of the selected physiological variables of strength in hip extension, knee extension and ankle plantar flexion, external work, and pre-, post and exercise heart rate to performance time in the Balke Treadmill test and in the Terminal Step test. Also, that a relationship does not exist between specific parameters of the Terminal Step test, that is, performance time, external work, exercise heart rate and recovery rate; and performance time in the Balke Treadmill test.

Symbolically, $H_0 : \rho = 0$.

Assumptions. Balke and associates (30, 31, 32, 33, 34) have reported that there are sufficient signs of physiological deterioration at a

heart rate of 180 beats per minute to justify the usefulness of this point as a measure of man's aerobic crest load - his aerobic capacity for physical work even though man's maximal working capacity usually reaches well beyond this point. Nagle and Bedecki (35) have supported the findings of Balke and associates.

In view of these findings, it is imperative that two assumptions be made with regard to the investigation of the relationship between the Terminal Step test and the Balke Treadmill test:

1. the Terminal Step test, as used in this study, is a test of man's capacity to perform physical work and

2. a heart rate of 180 beats per minute is the arbitrary cut-off point of man's aerobic capacity for maximal functional demands.

Delimitations. The scope of this study is concerned only with the anthropometrical and physiological variables selected, and with the specific chosen parameters of the Terminal Step test, with direct reference to healthy college freshmen entering the University of Alberta in the fall of 1963, and their performance on the Balke Treadmill test and the Terminal Step test.

Limitations. This study is limited by:

1. the number of subjects randomly selected. For the main problem of the study the number of subjects is 45, and for the subsidiary problem the number of subjects is 45. The total sample size is therefore ninety.

2. the methods and instruments employed,

3. the statistical procedures used to analyze the data and

4. the magnitude of experimental error by the investigator.

Definition of Terms.

Terminal Step Test: a test in which the subject steps up to and down from a 20 inch bench, 30 times per minute. The arbitrary termination point is when the subject's heart rate reaches 180 beats per minute.

It is an adapted form of the Harvard Step test.

Physical Work Capacity: the ability of an individual's circulo-respiratory system to take up, transport and give off oxygen to the muscle tissues enabling the individual to sustain prolonged physical work (36:153).

External Work: the effect of a force (the body) in producing a displacement (vertical ascent), measured by the product of the force and the amount of displacement in the line of action of the force.

Lower Limit for Terminal Heart Rate: a lower limit terminal heart rate of 175 beats per minute is to be utilized on the assumption that all subjects are not capable of attaining a terminal heart rate of 180 beats per minute.

REFERENCES

1. Johnson, R. E., Brouha, L., Darling, R. C., "A Test of Physical Fitness for Strenuous Exertion," Revue Canadienne de Biologie, vol. 1 (June 1942), pp. 491-503.

2. Brouha, L., Heath, C. W., Graybiel, A., "The Step Test: A Simple Method of Measuring Physical Fitness for Hard Muscular Work in Adult Men," Revue Canadienne de Biologie, vol. 2 (Feb. 1943), pp. 86-91.

3. Brouha, L., "The Step Test: A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men." Research Quarterly, vol. 14 (Mar. 1943), pp. 31-6.

4. Bookwalter, K. W., "A Study of the Brouha Step Test," The Physical Educator, vol. 5 (May 1948), p. 3.

5. Taddonio, D. A., Karpovich, P. V., "The Harvard Step Test as a Measure of Endurance in Running," Research Quarterly, vol. 22 (Oct. 1951), pp. 381-4.

6. Montoye, H. J., "The Harvard Step Test and Work Capacity," Revue Canadienne de Biologie, vol. 11 (Mar. 1953), pp. 491-99.

7. Eurard, E., "Use and Value of the Step Test in Military Pilot Selection," United States Armed Forces Medical Journal, vol. 10 (June 1959), pp. 659-74.

8. Brouha, L., Fradd, N. W., Savage, B. M., "Studies in Physical Efficiency of College Students," Research Quarterly, vol. 15 (Oct. 1944), pp. 211-24.

9. Sloan, A. W., Keen, E. N., "Physical Fitness of Oarsmen and Rugby Players Before and After Training," Journal of Applied Physiology, vol. 14 (July 1959), pp. 635-6.

10. Shay, C. T., "Effects of Specific Sports Upon Fitness," College Physical Education Association, 60th Annual Proceedings, 1957, pp. 67-73.

11. Gallagher, J. R., Brouha, L., "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, vol. 14 (Mar. 1943), pp. 23-30.

12. Karpovich, P. V., Starr, M. P., Weiss, R. A., "Physical Fitness Tests for Convalescents," Journal of the American Medical Association, vol. 126 (Dec. 1944), pp. 873-7.

13. Clarke, H. L., "A Functional Physical Fitness Test for College Women," The Journal of Health and Physical Education, vol. 14 (Sept. 1943), p. 358.

14. Hardy, H. L., Clarke, H. L., Brouha, L., "Testing Physical Fitness in Young Women," Revue Canadienne de Biologie, vol. 2 (Oct. 1943), pp. 407-15.

15. Sloan, A. W., "A Modified Harvard Step Test for Women," Journal of Applied Physiology, vol. 14 (Nov. 1959), pp. 985-6.

16. Gallagher, J. R., Brouha, L., "A Method of Testing the Physical Fitness of High School Girls," Revue Canadienne de Biologie, vol. 2 (Oct. 1943), pp. 395-406.

17. Brouha, L., Gallagher, J. R., "A Functional Fitness Test for High School Girls," The Journal of Health and Physical Education, vol. 14 (Dec. 1943), p. 517.

18. Miller, W. A., Elbel, E. R., "The Effect Upon Pulse Rate of Various Cadences in the Step-Up Test," Research Quarterly, vol. 17 (Dec. 1946), pp. 263-9.

19. Montoye, H. J., "An Investigation of Breath-Holding as a Measure of Cardiovascular Fitness," Doctoral Thesis, University of Illinois, 1950, Microcard.

20. Elbel, E. R., Reid, M., Ormond, D. E., "Comparison of Certain Tests of Physical Fitness and Certain Bodily Measurements," Journal of Applied Physiology, vol. 12 (Jan. 1958), pp. 37-41.

21. Karpovich, P. V., Physiology of Muscular Activity, 5th ed., Philadelphia: W. B. Saunders Co., 1959.

22. Fletcher, J. G., "Maximal Work Production in Man," Journal of Applied Physiology, vol. 15 (Sept. 1960), pp. 764-8.

23. Taylor, C., "A Maximal Pack Test of Exercise Tolerance," Research Quarterly, vol. 15 (Dec. 1944), pp. 291-302.

24. Cook, E. B., Wherry, R. J., " Statistical Evaluation of Physical Fitness Tests," Research Quarterly, vol. 21 (May 1950), pp. 94-111.

25. Cureton, T. K., Physical Fitness of Champion Athletes, Urbana: University of Illinois Press, 1951, p. 344.

26. Rasch, P. J., Cowell, H. S., Pierson, W. R., "The Correlation of the Bruce PFI with the Harvard Step Test," Revue Canadienne de Biologie, vol. 18 (Apr. 1959), pp. 77-82.

27. Taylor, C., "Some Properties of Maximal and Submaximal Exercises with Reference to Physiological Variation and the Measurement of Exercise Tolerance," American Journal of Physiology, vol. 142 (Sept. 1944), pp. 200-12.

28. Cullumbine, H., "Relationship Between Resting Pulse Rate, Blood Pressure and Physical Fitness," Journal of Applied Physiology, vol. 2 (Nov. 1949), pp. 278-82.

29. Henry, F. M., Berg, W. E., "Physiological and Performance Changes in Athletic Conditioning," Journal of Applied Physiology, vol. 3 (Aug. 1950), pp. 103-111.

30. Balke, B., "The Effect of Physical Exercise on the Metabolic Potential, a Crucial Measure of Physical Fitness," Exercise and Fitness, Athletic Institute, 1960, pp. 73-81.

31. Balke, B., Grillo, G. P. Konecci, E. B., Luft, U. C., "Work Capacity After Blood Donation," Journal of Applied Physiology, vol. 7 (Nov. 1954), pp. 231-8.

32. Wells, J. G., Balke, B., Van Fossan, D. D., "Lactic Acid Accumulation During Work. A Suggested Standardization of Work Classification," Journal of Applied Physiology, vol. 10 (Jan. 1957), pp. 51-55.

33. Balke, B., Ware, R. W., "An Experimental Study of Physical Fitness of Air Force Personnel," United States Armed Forces Medical Journal, vol. 10 (Jan. 1959), pp. 675-88.

34. Balke, B., Clark, R. T., "Cardio-Pulmonary and Metabolic Effects of Physical Training," Health and Fitness in the Modern World, Athletic Institute, 1961, pp. 82-9.

35. Nagle, F. J., Bedecki, T. G., "The Use of the Exercise Heart Rate Response as a Measure of Circulo-Respiratory Capacity," University of Florida. Article to the Writer, February, 1963.

36. Hettinger, T., Birkhead, N. C., Howarth, S. M., Issekutz, B., Rodahl, K., "Assessment of Physical Work Capacity," Journal of Applied Physiology, vol. 16 (Jan. 1961), pp. 153-6.

CHAPTER II

REVIEW OF THE LITERATURE

The review is subdivided into four sections:

1. literature pertaining to the Balke Treadmill test,

2. literature pertaining to the Step test,

3. reports on the effect of anthropometrical variables on treadmill and step test performance and

4. literature pertaining to the use of the heart rate as a measure of fitness.

Literature Pertaining to the Balke Treadmill Test. A progressive treadmill test has been devised by Balke and colleagues (1, 2, 3, 4, 5) to determine man's aerobic capacity for functional demands. Balke (6:74) has described this test as follows:

> Stress is gradually increased by elevating the slope in minute intervals. Thus, during walking at a constant speed of 3.4 m.p.h., the energy demands are gradually increased. These demands are met by proper adjustments of the cardio-respiratory systems: the increase in heart rate and in pulse pressure indicates the enlargement of the cardiac output, which is of primary importance for adequate oxygen and energy supply. The progressive demands on the respiratory system, handling the metabolic gas exchange, are expressed by the increase on pulmonary ventilation.

The test commenced with the subject walking on a horizontal grade. Each minute the slope of the treadmill was increased 1 percent, correspondingly increasing the work load. When the work load was such that the heart rate of the subject was 180 beats per minute, the test was terminated. Balke's observations were, ". . . that it is at about this heart rate that signs of physiological deterioration occur" (7:1). These were reflected by a decrease in pulse pressure and oxygen pulse, a respiratory exchange ratio

reaching and exceeding unity, a disproportionately sharp rise in respiratory rate and minute volume and a sudden decrease in alveolar carbon dioxide tension. Balke indicated that at this heart frequency, the time for sufficient ventricle filling between contractions was too short.

The methodology employed by Balke and colleagues has varied to some degree, apparently adjusted to the problem of investigation, to the apparatus available, and/or to the developmental processes. In all instances, the treadmill test began with the treadmill platform in the horizontal position, while the speed of the treadmill belt and the work load increase have varied; but remained respectively constant within each study. The speed of the treadmill belt has been reported as fluctuating between 90 meters per minute (5) and 92 meters per minute (2, 3, 4). The work load has been increased by elevating the angle of the treadmill in one of three ways, a) 1/2 percent of the belt distance travel per minute at the end of the first minute and each minute thereafter (2); b) 1 percent per minute at the end of each minute throughout the test (3, 5, 8); and c) 2 percent at the end of the first minute and 1 percent per minute for each minute thereafter (1, 4).

Billings, et al (9) and Nagle and Bedecki (7) have supported the findings of Balke and colleagues concerning the fact that functional limitations occur at a heart rate of 180 beats per minute.

In an effort to define a simple, precise measure of cardiovascular response to exercise, Billings, et al (9) investigated Balke's progressive walking treadmill test. Twenty-six male university students were used and the progressive treadmill test was administered to each subject on several occasions. The treadmill jack employed in this study made it possible to impose progressively greater work loads for only 19 minutes. The authors found that heart rate adaptation to each new level of exercise was complete within one minute even at higher work loads, and that the respiratory ex-

change ratio determined during the final minute of exercise was above unity in every case. They (9:1003) stated: ". . . this test induces physiologic changes ranging from slightly above resting values for heart rate, ventilation and O_2 uptake to or above the maximum attainable steadystate values for these functions, and that these changes are made to occur gradually."

Nagle and Bedecki (7), utilizing 44 male students and faculty members, scrutinized the use of Balke's method as a measure of circulo-respiratory capacity. Their test of circulo-respiratory capacity consisted of an all-out run on a motor driven treadmill. They found that 1) the correlation coefficient between the time for the heart rate to reach 180 beats per minute and the criterion measure of all-out run time was 0.852; 2) the oxygen consumption tended to level off at a heart rate of 180 beats per minute indicating decreased transport of oxygen despite increased heart action; 3) the oxygen consumption per unit of work done revealed a trend toward acute aerobic work near the 180 heart rate; 4) ventilation increased linearly with oxygen consumption and the heart rate until at or near a heart rate of 180 beats per minute, the ventilation function became inefficient and 5) the respiratory quotient reached unity near a heart rate of 180 beats per minute. Among their conclusions, they (7:4) stated: ". . . The 180 heart rate is related to manifestations of physiological incompetence . . . and this can be demonstrated within an intensity range in the exercise stress."

Billings, <u>et al</u> (9:1004) stated: ". . . that the accurate recording of heart rate changes alone can provide a reasonably accurate approximation of the work capacity as measured by this procedure, without the use of apparatus other than a treadmill, an electrocardiogram, and a stopwatch."

Nagle and Irwin (10), investigating the effects of two systems of

weight training on circulo-respiratory endurance, have utilized the arbitrary cut-off point of a heart rate of 180 beats per minute to terminate two bicycle ergometer tests. The authors (10:610) stated:

> Balke says that this technique affords a measure of maximal performance by forcing the test to a point near exhaustion. However, the end point is established by physiological observation and measurement rather than the subject's will to co-operate. This technique obivously eliminates the subjectivity involved in an endurance test in which an individual supposedly continues exercise to the point of exhaustion.

Several investigators (11, 12, 13, 14) at the University of Alberta have utilized Balke's progressive treadmill performance test to study the effect of various exercise programs on certain physiological responses and as a measure of cardio-respiratory fitness.

Alexander, et al (15) have completed the first of a series of studies investigating the contribution of various intercollegiate athletics upon physical fitness as assessed by Balke's progressive treadmill test. This first study was concerned with three sports, hockey, skiing and wrestling.

Howell, et al (16) investigated the effects of giving and not giving blood upon treadmill performance time using Balke's test.

Dempsey and Hodgson (17) investigated the relationship between treadmill performance, body composition and body mass in young men. Balke's progressive treadmill test was employed.

Literature Pertaining to the Harvard Step Test. Johnson, et al (18), in 1942, described a rapid simple means of measuring man's physical fitness for strenuous exertion. They utilized one of several forms of exercise that, prior to their report, had proven ". . . useful in picking out the best, the worst and the average in groups of healthy normal men,

and in following variations in the physical condition of a given subject examined at intervals" (18:491).

The exercise criteria were a) that each subject worked at a constant rate proportional to his body weight, b) that the exercise required no special skill and c) that the exercise involved large muscle groups putting the cardiovascular and respiratory systems under definite stress. By exposing subjects to an exercise of this form, in which no one was able to perform in a steady state for more than five minutes, a satisfactory estimate of man's physical fitness was obtained from a proposed index of fitness:

$$= \frac{\text{Duration of a standard exhausting exercise in seconds x 100}}{\text{2 x sum of pulses from 1-1 1/2', 2-2 1/2', 4-4 1/2' in recovery}}$$

(18:492).

This proposed index of fitness for hard work was based on the pulse recovery curve equation:

$$Y = ae^{-kt} + b$$

where "a" & "b" were constants, "t" was the time after stopping work, and "k" had dimensions of a velocity constant. Since the heart rate at any time "t" in recovery was equal to a definite intergral of the curve of the pulse from thirty seconds before "t" to thirty seconds after "t", and since three different values of "Y" were sufficient to define the curve, computation of the whole curve was approximately given by multiplying two by the summation of the indicated pulse rates (18:493).

The most simple type of exercise employed in this test was the step test as outlined by Brouha, et al (19). This test consisted of having the subject step up to and down from a twenty inch platform thirty times per minute for five minutes, unless he stopped from exhaustion prior to the end of the fifth minute. Upon completion of the work,

the subject was seated and the pulse count was taken for three - thirty second intervals from 1 - 1 1/2, 2 - 2 1/2, and 3 - 3 1/2 minutes. The subject's index of fitness was then calculated according to the formula previously described with one minor adjustment. A pulse count from 3 - 3 1/2 minutes was employed in place of the 4 - 4 1/2 minute pulse count.

The resulting score or scores were interpreted as follows (20:285):

Below 55 = Poor physical condition
55 - 64 = Low average
65 - 74 = High average
80 - 90 = Good
Above 90 = Excellent.

Since the original development of this index of fitness, a rapid form has been established. In this form, the pulse count was taken only once - from 1 - 1 1/2 minutes and the score was obtained from the formula (20:285):

$$\text{Index of Fitness} = \frac{\text{Time of stepping in seconds} \times 100}{5.5 \times \text{pulse count.}}$$

The interpretation of scores calculated on this rapid form was (20:286):

Below 50 = Poor
50 - 80 = Average
Above 80 = Good.

This step test was originally designed to measure the dynamic physical fitness of healthy adult men for hard muscular work. Subsequent to its development, it has been modified and made applicable for estimating the dynamic physical fitness of boys (21), young women (22, 23), and adolescent girls (24). These modifications were:

1. for boys, 13-19 years of age, with a body surface area less than 1.85 square meters, an 18" bench at a stepping cadence of 30 per minute for a maximum of 4 minutes was used. If the body surface area was greater than 1.85 square meters, the bench height was increased to twenty inches;

2. for young women, 18 years of age and older, an 18" bench at a cadence of 30 steps per minute for a maximum of 4 minutes was utilized and

3. for adolescent girls, 13-18 years of age, a 16" bench, at the same stepping cadence and for the same test duration as for young women, was employed.

In all instances, the formula for calculating the index of fitness was the same as the original.

Prior and subsequent to the development of the Harvard Step test, many investigators have frequently utilized a form of bench or platform stepping as the exercise in the test situation. Consequently, depending on the area of study, the nature of the experiment and the preference of the investigator, variations in stepping height (12 to 22 inches), in cadence of stepping (20 to 50 steps per minute) and in duration of stepping (15 seconds to exhaustion) have arisen.

In direct reference to the form of step test to be employed in this investigation - a 20 inch platform, 30 steps per minute till heart rates reaches 180 beats per minute - there has been only one closely related series of investigations. Cullumbine, et al (25, 26, 27) in a series of three studies concerned with the physical fitness of 7,000 Ceylonese subjects, utilized an Exhaustion Step test. This test consisted of stepping up to and down from a 20 inch platform 30 times per minute for as long as possible. The time taken to complete this test

was the exhaustion index. This index was one of the functional indications of physical fitness.

Effect of Anthropometrical Variables on Treadmill and Step Test Performance. In developing a rapid simple test of dynamic physical fitness from which the original Harvard Step test was derived, Johnson, et al (18:495) stated: ". . . all subjects must work at a rate linearly proportional to the body weight" so that neither the light man nor the heavy man is favoured.

Seltzer and Brouha (28) investigated the influence on physical fitness of one element in body build, namely the masculine component. Using the Harvard Step test as a means of measuring the physical fitness of 1,173 college men prior to training and 725 college men after a training program, they stated that college men with a high degree of the masculine component - reciprocal ponderal index - achieved better scores than those individuals weak in masculinity.

Clarke (22), utilizing a modified form of the Harvard Step test - an 18 inch bench, 30 step-ups per minute for a maximum of 4 minutes - for college women, reported that the effects of height and weight on performance were negligible. Since each individual had the normal problem of moving his own body up and down in this test, all subjects were equalized.

In conjunction with Clarke's study, Hardy, et al (23:412) stated:

> The question has been raised as to whether or not the test is easier for a tall subject than for a short one. Experiments on several hundred subjects have proven that for young men as well as for young women this factor is not worth considering. There are just as many low and high scores among the short subjects as among the tall.

Gallagher and Brouha (29) reported that the individual's

mass is more related to the work load in the Harvard Step test than a slight variation in stepping height. "A very careful adjustment of step height to the size of the individual is neither necessary nor practical: the work load is determined more by the individual's mass, which must be lifted through space, than by a slight variation in the distance through which that mass is lifted" (29:396).

In 1944, Taylor (30) designed a test to measure exercise tolerance. This test was the pack test. The subject, wearing a pack-sack on his back, with an initial weight of 10 pounds inside, stepped up and down on an 18 inch bench at a cadence of 40 steps per minute. Every two minutes a 10 pound weight was added to the sack until the subject was no longer able to execute the full ascent-descent cycles at the proper cadence. Testing 700 men aged 16-46, Taylor found that performance - time to exhaustion was independent of body weight but was slightly favoured by body height ($r = 0.36$). Consequently, the author devised a weighting system by making 16 seconds equivalent to 1 inch of height. Subjects who were 70 inches tall received no weighting. Subjects who were more than, or less than, 70 inches tall had 16 seconds per inch subtracted from, or added to, their performance time, respectively.

Using 306 aviation cadets and 500 college students, Seltzer (31) studied the relationship of a few anthropometric measures with dynamic physical fitness as indicated by the Harvard Step test, Taylor's Pack test and a treadmill test. As well, he investigated the necessity of making corrections for variations in stature and leg length. He concluded that 1) there was no relationship between stature, weight, lower extremity length and lower leg length with physical fitness indices derived from the Step test and Pack test; 2) there was no rela-

tionship between absolute stature or leg length and the physical fitness index obtained by the treadmill test and 3) there was no evidence of any appreciable advantage in physical fitness scores of tall, long-legged individuals. Body-build, as exemplified by reciprocal ponderal index, was related to degrees of physical efficiency, ". . . at least insofar as this is indicated by the Step, Pack, and Treadmill Tests" (31:17).

Seltzer (31:20) stated:

> This study also indicates the general futility to obtain significant relationships between general physical capacity and isolated linear or volumetric measurements. The organism cannot be dissected in this manner and still yield profitable relationships with measures of general physical capacity. Emphasis should be placed on the total physique and less on its individual parts.

Bookwalter (32) found that Step test scores were not related to height or weight. In this study, the Brouha Step test was administered to 1,269 Armed Services Training Program students at Indiana University.

One aspect of a series of investigations by Cullumbine and colleagues (25, 26, 27) was concerned with the relationship between certain anthropometrical measurements and the physical fitness indices obtained from three Step tests: 1) the Harvard Step test, 2) an Endurance Step test - 20 inch bench, 45 steps per minute for as long as possible and 3) an Exhaustion Step test - 20 inch bench, 30 steps per minute for as long as possible. These three tests were administered to 7,000 Ceylonese subjects aged 10 and up. Cullumbine (25), reporting the statistical analysis of data, concluded that, for the group of males 21-25 years old, 1) the Harvard Step test index correlated significantly with bi-iliac diameter/height; chest circumference/height; the bi-iliac diameter and the bi-zygomatic diameter and 2) the Exhaustion Step test score correlated significantly with weight,

height and leg length at the 0.01 level of confidence.

Miller and Elbel (33) investigated the effect upon pulse rate of various cadences in the Step test. They stated that a 16 inch bench was preferred in this study because subjects were unable to maintain the rhythm (rapid cadences) on an 18 or 20 inch bench.

In 1953, Montoye (34) utilized Brouha's Step test modified to 17 inches, to study breath holding as a measure of cardivoscular fitness. He indicated preference for this bench height because he felt that the tempo of stepping was hard to maintain on a 20 inch bench for the average subject.

Cureton (35:345) expressed the opinion that one of the factors dominating performance in a standard treadmill walk - 3.5 miles per hour on an 8.6% grade - was the length of the legs.

Using 50 college males, Montoye (36) investigated the relationship between the original Harvard Step test with several other criteria of work performance and with certain body measurements. Among his conclusions, he (36:497) stated: "No significant relationship between the Fitness index and height, weight or surface area was observed. . ."

Elbel, et al (37) studied the relationship between the scores from the original Harvard Step test with certain bodily measurements in 50 male university students. Weight and height were significantly correlated to the Step test index at the 0.01 level of confidence. Leg length - greater trochanter to the floor - was significantly correlated to the Step test index at the 0.05 level of confidence but this was not considered to be large enough to justify a conclusion of actual significance. They (37:40) stated: "Further investigation of the relation of the Harvard Step-Test to anthropometric measures seems

warranted and certainly would be prerequisite to any recommendation of specific changes in Step-Test procedure."

Karpovich (20:288) expressed the opinion that the drawbacks of the original Harvard Step test were 1) the bench was too high and 2) acute local muscular fatique was possible.

Two groups, one of 46 medical students and one of 22 physical education students, were given the original Harvard Step test by Keen and Sloan (38). No significant correlation was found between test index scores and weight, height, leg length - height of iliac crest above the ground and bi-iliac diameter. Keen and Sloan felt that there was no justification for lowering the step height for shorter adult men.

Eurard (39), using the original Harvard Step test as a possible means of military pilot selection, reported no statistically significant correlations between the step test index with height-weight ratio or with leg length - wall to the soles of feet in the sitting position. The subjects were 3,329 males aged 17-27.

> Statistical calculations demonstrated that the height-weight ratio and leg length have no significant influence on the results of the step test, within the limits described here. Because of the lack of sufficient number of subjects, it was not possible to collect data on subjects having legs shorter than 100 cm. (39:662).

Fletcher (40) studied the ability of 12 men, aged 20-46, to perform hard muscular work by stepping up to and down from a 22 inch bench, 30 times per minute till exhaustion. He observed that obese subjects found it rather difficult to maintain balance while stepping.

One aspect of a study by Hettinger, et al (41) compared the performance of 96 men aged 23-62 on the Harvard Step test (original form) to that on a new step test in which adjustments were made for

body weight and leg length. "Although the modified step test was designed to eliminate the unfairness of the Harvard step test to subjects with short legs by adjusting the step height according to the length of the lower extremity . . ., it appears, at least on the basis of this material, that the modified step test does not offer any striking advantage over the standard Harvard step test" (41:156).

Sloan (42) utilized a modified Harvard Step test - an 18 inch bench and maximal test duration of 4 minutes - to measure the effects of training on the physical fitness of 61 women student teachers aged 17-20. Among her conclusions, she reported that there was no relationship between height and Step test index score or between weight and the index score.

Dempsey and Hodgson (17), investigating the relationship between treadmill performance, body composition and body mass in sedentary young men, found no statistically significant relationship between height or weight and treadmill performance. Percent body fat and fat free body weight were significantly correlated to treadmill performance at the 0.001 level of confidence. Relative weight was significantly correlated to treadmill performance at the 0.05 level of confidence.

<u>Use of the Heart Rate as a Measure of Fitness</u>. The heart rate, in spite of its limitations as a measure of circulatory response to exercise, has frequently been used as an indicator of fitness (40, 43, 44, 45, 46). The Physical Efficiency Index was devised by Gallagher, Brouha and Darling (18) based on the principle that the rate at which the heart recovered after strenuous exercise provided a means of estimating dynamic physical fitness. That this assumption was true has been demonstrated by the improvement of the index from week to week during a period of training (47), by a reduction of the

index after breaking training (47), under the stress of inadequate diet or after an acute illness, and by a subsequent gradual rise on resuming exercise or shift to a proper diet (48).

However, the relationship of the heart rate before, during and after exercise in different states of fitness has not been clearly defined. Brouha and Heath (49:477) stated: "There is no satisfactory relation between basal pulse, sitting pulse and physical fitness for strenuous exertion in normal, healthy young men." No measurement of pulse rate, taken at rest, has indicated man's capacity to perform hard work, although, pulse rate during recovery from hard exercise has shown a good relation to man's fitness for strenuous exertion (49). In contrast to this, Cullumbine (26), Cogswell, et al (44) and Keen and Sloan (38) have shown that a low pre-exercise resting pulse was associated with a low post-exercise pulse and a correspondingly high fitness index.

Elbel, et al (37) found a negative correlation, statistically significant at the 0.01 level of confidence, between the original Harvard Step test index and pre-exercise pulse, which conflicted with the work of Brouha and associates. As well, Elbel, et al (37:40) very carefully extracted data from two studies by Gallagher and Brouha in the Yale Journal of Biology and Medicine, 1943, and redetermined the correlation coefficients between pre-exercise pulse rate and physical fitness indices. They found that the coefficients of correlation were consistent with their present findings.

Elbel (50) reported very little relationship between pre-exercise and post-exercise pulse rates. In a later study, Elbel and Holmer (51) found that the correlation coefficient between the pre-exercise pulse rate and the time required for the post-exercise pulse

to return to the pre-exercise level was insignificant. Also, the pre-exercise pulse rate was not related to a pulse rate increase due to a two minute period of exercise.

Morehouse (52:27,28), investigating the response of the heart to various forms of exercise, stated:

> 1. The reliability of the pulse rate for two minutes after exercise is directly related to the strenuousness of the exercise.
>
> . . . .
>
> 7. The recovery time is prolonged in relation with the intensity of exercise and is not related to the resting pulse.
>
> 8. In general, where exercises are used to differentiate individuals on the basis of post-exercise pulse rate, the pulse ratio and recovery time, they must be strenuous in order to give reliable results.

In reporting results of physical fitness research in the Army Air Forces up to and including the year 1943, it was stated: "No relationship is found between the state of physical fitness and cardiovascular-respiratory ratings namely: character of pulse, systolic pressure, diastolic pressure, sitting normal pulse rate, pulse rate immediately after exercise, and pulse rate two minutes after exercise" (52:14).

Taylor (54:210), whose findings were supported by Pierson and Rasch (55:79), stated:

> . . . the inter-individual comparisons of heart rate following maximal exercise . . . . likewise offer no promise for a reliable measure of fitness as determined by time-run. Recovery of heart rate during the first three minutes after sub-maximal work is likewise unpromising . . .

> the lack of consistent differentiation . . . invalidates the recovery function, which has been advocated as a measure of fitness . . . . It seems clear that one must look to the responses during exercise, particularly the later phases of adaptation, for critical measures of fitness for hard work, not to the resting or recovery states.

Billings, et al (9) reported that there was no relationship between the ability to work to exhaustion and the rate of recovery in heart rate.

They (9:1005) stated:

> It appears . . . that pulse rates during recovery from exercise may be of some value in ranking subjects exposed to light or moderate work loads . . . . however . . . there is no correlation between ability to sustain maximal or exhausting work and the heart rate pattern during recovery.

Astrand (56), Billings, et al (9) and Janda (57) have supported Taylor's (54) views. They have indicated that if the physical fitness of an individual, in terms of physical work capacity, is to be examined, the response of the cardiovascular-respiratory systems to hard work should be made during muscular work.

Balke, et al (2, 4, 5) have found that during muscular work on a treadmill test several clearly discernible physiologic alterations occurred. The respiratory exchange ratio reached and exceeded unity; the pulse pressure and oxygen pulse became maximal; the alveolar carbon dioxide tension dropped suddenly, and respiratory rate and minute volume rose sharply in a disproportionate manner. In most instances, these findings appeared at/or about the time at which the heart rate attained 180 beats per minute. Wells, et al (4) reported that about this same heart

rate, blood lactate levels began to rise sharply. Therefore, man's aerobic capacity for physical work was reported in terms of performance time - the time taken for the heart rate to reach 180 beats per minute.

REFERENCES

1. Balke, B., "Correlation of Static and Physical Endurance," Report No. 1, Randolph Field, Texas: School of Aviation Medicine, April 1952, Project Number 21-32-004. Article to the Writer, May 1963.

2. Balke, B., Grillo, G. P., Konecci, E. B., Luft, U. C., "Work Capacity after Blood Donation," Journal of Applied Physiology, vol. 7 (Nov. 1954), pp. 231-8.

3. Schilling, J. A., Harvey, R. B., Becker, E. L., Velasquez, T., Wells, G., Balke, B., "Work Performance at Altitude After Adaptation in Man and Dog," Journal of Applied Physiology, vol. 8 (Jan. 1956), pp. 381-7.

4. Wells, J. G., Balke, B., Van Fossan, W. D., "Lactic Acid Accumulation During Work. A Suggested Standardization of Work Classification," Journal of Applied Physiology, vol. 10 (Jan. 1957), pp. 51-55.

5. Balke, B., Ware, R. W., "An Experimental Study of Physical Fitness of Air Force Personnel," United States Armed Forces Medical Journal, vol. 10 (June 1959), pp. 675-88.

6. Balke, B., "The Effect of Physical Exercise on the Metabolic Potential, a Crucial Measure of Physical Fitness," Exercise and Fitness, Athletic Institute, 1960, pp. 73-81.

7. Nagle, F. J., Bedecki, T. G., "The Use of the Exercise Heart Rate Response as a Measure of Circulo-Respiratory Capacity," University of Florida. Article to the Writer, February 1963.

8. Balke, B., Clark, R. T., "Cardio-Pulmonary and Metabolic Effects of Physical Training," Health and Fitness in the Modern World, Athletic Institute, 1961, pp. 82-9.

9. Billings Jr., C. E., Tomashefski, J. F., Carter, E. T., Ashe, W. F., "Measurement of Human Capacity for Aerobic Muscular Work," Journal of Applied Physiology, vol. 15 (Nov. 1960), pp. 1001-1006.

10. Nagle, F. J., Irwin, L. W., "Effects of Two Systems of Weight Training on Circulo-Respiratory Endurance and Related Physiological Factors," Research Quarterly, vol. 31 (Dec. 1960), pp. 607-15.

11. Alexander, J., Howell, M. L., Fraser, R., Sproule, B., "An Evaluation of the 5BX Program of Exercises by Certain Physiologic Responses to a Treadmill Test, "Unpublished Paper, University of Alberta, 1962.

12. Hodgson, J. L., "The Effect of Circuit Training and Isometric Exercises on Treadmill Performance," Unpublished Master's Thesis, University of Alberta, 1963.

13. Dempsey, J. A., "An Analysis of Exercise Induced Total Body Weight Changes in Obese and Non-Obese College Males," Unpublished Master's Thesis, University of Alberta, 1963.

14. Cooper, L. A., "A Comparison of the Effects of Short Intensive and Prolonged Intensive Exercise Programs on Certain Cardio-Respiratory Functions," Unpublished Master's Thesis, University of Alberta, 1963.

15. Alexander, J., Howell, M. L., Fraser, R., Sproule, B., "Contributions of Various Sports to Physical Fitness as Assessed by Physiological Responses to a Treadmill Performance Test," Unpublished Paper, University of Alberta, 1963.

16. Howell, M. L., Coupe, K., "Effect of Blood Loss Upon Performance in the Balke - Ware Treadmill Test," Research Quarterly, vol. 35 (May 1964), pp. 156-165.

17. Dempsey, J. A., Hodgson, J. L., "The Relationship Between Treadmill Performance, Body Composition, and Body Mass in Obese, and Non-Obese, Sedentary and Active Young Men," A Paper given to the Research Section of C.A.H.P.E.R., Saskatoon, June 1963.

18. Johnson, R. E., Brouha, L., Darling, R. C., "A Test of Physical Fitness for Strenuous Exertion," Revue Canadienne de Biologie, vol. 1 (June 1942), pp. 491-503.

19. Brouha, L., Heath, C. W., Graybiel, A., "The Step Test: A Simple Method of Measuring Physical Fitness for Hard Muscular Work in Adult Men," Revue Canadienne de Biologie, vol. 2 (Feb. 1943), pp. 86-91.

20. Karpovich, P. V., Physiology of Muscular Activity, 5th ed., Philadelphia: W. B. Saunders Co., 1959.

21. Gallagher, J. R., Brouha, L., "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, vol. 14 (Mar. 1943), pp. 23-30.

22. Clarke, H. L., "A Functional Physical Fitness Test for College Women," The Journal of Health and Physical Education, vol. 14 (Sept. 1943), pp. 358.

23. Hardy, H. L., Clarke, H. L., Brouha, L., "Testing Physical Fitness in Young Women," Revue Canadienne de Biologie, vol. 2 (Oct. 1943), pp. 407-15.

24. Brouha, L., Gallagher, J. R., "A Functional Fitness Test for High School Girls," The Journal of Health and Physical Education, vol. 14 (Dec. 1943), p. 517.

25. Cullumbine, H., "Relationship Between Body Build and Capacity for Exercise," Journal of Applied Physiology, vol. 2 (Sept. 1949), pp. 155-68.

26. Cullumbine, H., "Relationship Between Resting Pulse Rate, Blood Pressure and Physical Fitness," Journal of Applied Physiology, vol. 2 (Nov. 1949), pp. 278-82.

27. Cullumbine, H., Bibile, S. W., Wikramanayake, T. W., Watson, R. S., "Influence of Age, Sex, Physique and Muscular Development on Physical Fitness," Journal of Applied Physiology, vol. 2 (Mar. 1950), pp. 488-511.

28. Seltzer, C. C., Brouha, L., "The Masculine Component and Physical Fitness," American Journal of Physical Anthropology, vol. 1 (Mar. 1943), pp. 95-108.

29. Gallagher, J. R., Brouha, L., "A Method of Testing the Physical Fitness of High School Girls," Revue Canadienne de Biologie, vol. 2 (Oct. 1943), pp. 395-406.

30. Taylor, C., "A Maximal Pack Test for Exercise Tolerance," Research Quarterly, vol. 15 (Dec. 1944), pp. 291-302.

31. Seltzer, C. C., "Anthropometric Characteristics and Physical Fitness," Research Quarterly, vol. 17 (Mar. 1946), pp. 10-20.

32. Bookwalter, K. W., "A Study of the Brouha Step Test," The Physical Educator, vol. 5 (May 1948), p. 3.

33. Miller, W. A., Elbel, E. R., "The Effect Upon Pulse Rate of Various Cadences in the Step-Up Test," Research Quarterly, vol. 17 (Dec. 1946), pp. 263-9.

34. Montoye, H. J., "An Investigation of Breath-Holding as a Measure of Cardiovascular Fitness," Doctoral Thesis, University of Illinois, 1950, Microcard.

35. Cureton, T. K., Physical Fitness of Champion Athletes, Urbana: University of Illinois, 1951.

36. Montoye, H. J., "The Harvard Step Test and Work Capacity," Revue Canadienne de Biologie, vol. 11 (Mar. 1953), pp. 491-99.

37. Elbel, E. R., Reid, M., Ormond, D. E., "Comparison of Certain Tests of Physical Fitness and Certain Bodily Measurements," Journal of Applied Physiology, vol. 12 (Jan. 1958), pp. 37-41.

38. Keen, E. N., Sloan, A. W., "Observations on the Harvard Step Test," Journal of Applied Physiology, vol. 13, (Sept. 1958), pp. 241-3.

39. Eurard, E., "Use and Value of the Step Test in Military Pilot Selections," United States Armed Forces Medical Journal, vol. 10 (June 1959), pp. 659-74.

40. Fletcher, J. G., "Maximal Work Production in Man," Journal of Applied Physiology, vol. 15 (Sept. 1960), pp. 764-8.

41. Hettinger, T., Birkhead, N. C., Howarth, S. M., Issekutz, B., Rodahl, K., "Assessment of Physical Work Capacity," Journal of Applied Physiology, vol. 16 (Jan. 1961), pp. 153-6.

42. Sloan, A. W., "Effect of Training on Physical Fitness of Women Students," Journal of Applied Physiology, vol. 16 (Jan. 1961), pp. 167-9.

43. Steinhaus, A. H., "Chronic Effects of Exercise," Physiological Reviews, vol. 13 (1933), pp. 103-47.

44. Cogswell, R. C., Henderson, C. R., Berryman, G. H., "Some Observations on the Effects of Training on Pulse Rate, Blood Pressure and Endurance in Humans, Using the Step Test, Treadmill and Electrodynamic Brake Bicycle Ergometer," American Journal of Physiology, vol. 146 (June 1946), pp. 422-30.

45. Henry, F. M., "Influence of Athletic Training on the Cardiovascular System," Research Quarterly, vol. 25 (May 1954), pp. 28-40.

46. Sloan, A. W., Keen, E. N., "Physical Fitness of Oarsmen and Rugby Players Before and After Training," Journal of Applied Physiology, vol. 14 (July 1959), pp. 635-6.

47. Brouha, L., Fradd, N. W., Savage, B. M., "Studies in Physical Efficiency of College Students," Research Quarterly, vol. 15 (Oct. 1944), pp. 211-24.

48. Johnson, R. E., Darling, R. C., Forbes, W. H., Brouha, L., Egana, E., Graybiel, A., "The Effect of A Diet Deficient in Part of the Vitamin B Complex on Men Doing Manual Labor," Journal of Nutrition, vol. 24 (1942), pp. 585-96.

49. Brouha, L., Heath, C. W., "Resting-Pulse and Blood Pressure Values in Relation to Physical Fitness in Young Men," The New England Journal of Medicine, vol. 228, (April 1943), pp. 473-7.

50. Elbel, E. R., "The Relationship Between Pre-Exercise and Post Exercise Pulse Rate," Research Quarterly, vol. 19 (Oct. 1948), pp. 222-8.

51. Elbel, E. R., Holmer, R. M., "The Relationship Between Pre-Exercise Pulse Rate and Recovery Following Exercise," Research Quarterly, vol. 20 (Dec. 1949), pp. 367-77.

52. Morehouse, L., "A Study of the Response of the Heart to Various Types of Exercise," Doctoral Thesis, University of Iowa, 1941, Microcard.

53. Army Air Forces, "Army Air Forces Physical Fitness Testing Program," Research Quarterly, vol. 15 (Mar. 1944), pp. 12-15.

54. Taylor, C., "Some Properties of Maximal and Submaximal Exercise with Reference to Physiological Variation and the Measurement of Exercise Tolerance," American Journal of Physiology, vol. 142 (Sept. 1944), pp. 200-12.

55. Pierson, W. R., Rasch, P. J., "Bruce Physical Fitness Index as a Predictor of Performance in Trained Distance Runners," Research Quarterly, vol. 31 (Mar. 1960), pp. 77-81.

56. Astrand, P.-O., "Human Physical Fitness with Special Reference to Sex and Age." Physiological Reviews, vol. 36 (July 1956), pp. 307-35.

57. Janda, F., "A Point in the Discussion on the Physical Fitness of Youth," The Journal of Sports, Medicine and Physical Fitness, vol. 2 (June 1962), p. 121.

CHAPTER III

METHODS AND PROCEDURE

Subjects. During freshmen registration at the University of Alberta in September of 1963, fifty-five male subjects were selected utilizing a table of random numbers from Dixon and Massey (1:366-70). Only forty-five of the initial fifty-five subjects were employed in this study. An allowance of ten was made for those subjects designated medically unfit to participate in this experiment and for those not reporting on their initial respective testing day.

In order to determine the validity of the multiple regression equation established between specific terminal step test parameters to performance time in the Balke treadmill test and to construct a normative table for performance times in both tests an additional forty-five subjects, not previously selected, were drawn from the freshmen required physical education service classes in January 1964, utilizing the same table of random numbers (1).

Anthropometrical Measurements.

Weight and Height. A Detecto-Medic Spring Scale (made by Detecto Scales Inc., Brooklyn, New York) was used to weigh each subject, who was dressed in T-shirt, gym shorts and socks. Weight was recorded to the nearest half pound and converted to kilograms. An anthropometer, calibrated in inches, and attached to the Detecto-Medic Spring Scale, was employed in measuring the erect body length from the soles of the feet, in socks, to the vertex of the skull. Height was measured to the nearest quarter

of an inch, converted to meters and recorded.

Leg Length. While the subject was still in the erect body position for the measurement of height, the greater trochanter of the femur was located by palpating the upper femoral area. The corresponding skin surface point was marked by means of a black pencil. The vertical distance between this point and the platform of the Detecto-Medic Spring Scale was determined with a measuring tape to the nearest quarter of an inch, converted into meters and recorded.

Leg Length/Height Ratio. Using the arithmetic mean of three previously determined measurements of leg length and height, both in metric units, a leg length/height ratio was calculated for each subject and recorded.

Weight, height and leg length measurements were taken three times for each subject and the respective arithmetic mean of each, in the corresponding units, was recorded.

Physiological Measurements.

Strength. Clarke's Cable Tension Methods (2) for measuring muscular strength were employed. For each subject, the bilateral strength of the hip extensors, knee extensors and the plantar flexors of the ankle were determined. Measurements were taken twice for each of the three different muscle groupings with a one minute rest period between trials. The arithmetic mean of the two respective trials was calculated, converted from pounds to kilograms and recorded.

Heart Rate. Three surface electrodes, one strapped to the forehead and two strapped to the chest, one immediately below and to the lateral side of each nipple, and minutely coated

with Redux electrode paste to reduce skin resistance, were connected to the leads of a Sanborn Electrocardiograph (Model 51, Serial 12177, Cambridge, Mass.) or a Sanborn Viso-Cardiette (Model 100). From the record of the electrocardiogram, which is a graphic record of certain electrophysiologic phenomena manifested by the heart during the phases of contraction and relaxation transmitted through the electrocardiograph, the heart rate was calculated in beats per minute.

Using the aforementioned method, heart rates were recorded at specific times. These were:

1. pre-exercise standing heart rate - the last five seconds of each half minute for two minutes,

2. exercise heart rate - the last five seconds of each half minute of performance and

3. post-exercise standing heart rate - the last five seconds of each half minute for seven minutes.

When the exercised heart rate reached 170 beats per minute, heart rate readings were taken every ten to fifteen seconds till the terminal heart rate was attained.

Performance Time. Performance time was the time from the beginning of the exercise to the termination of exercise recorded to the nearest tenth of a minute. Exercise was terminated for all subjects at a heart rate of 180 beats per minute or at a slightly lower heart rate if the electrocardiogram indicated a levelling off effect - three similar consecutive heart rate readings slightly below 180 beats per minute.

External Work. Upon completion of the work capacity tests performed by each subject, the amount of external work was

calculated in metre-kilograms per minute for the Balke Treadmill test and in metre-kilograms for the Terminal Step test and recorded.

a) Work-Grade Walking on Treadmill (3:1010)

$= \text{Mass (body weight)} \times \text{Speed} \times \sin \alpha$ (α being the gradient).

b) Work-Step Test

$= \text{Mass (body weight)} \times \text{Height of bench} \times \text{No. of steps taken}$

WORK CAPACITY TESTS

1. The Balke Treadmill Test (4). This test consisted of walking on a motor driven aluminum treadmill (Model 18-49-B, Serial 125, made by the W. E. Quinton Instrument Co., Seattle, Wash.) at 91.2 ± 2.7 metres per minute (3.4 ± 0.1 mph) starting on a horizontal grade. While the treadmill speed remained constant throughout the test, the work load was gradually increased by elevating the angle of the treadmill 1 percent of the belt distance travel per minute at the end of the first minute and each minute thereafter. When the heart rate reached 180 beats per minute, the test was terminated by stopping the treadmill and lowering the platform to a level grade.

Test Instructions. Standardized test instructions were given to each subject:

"a) You are to stand on the treadmill platform and will begin walking in a normal manner as soon as the treadmill is started.

b) You will continue to exercise in this manner until the treadmill is stopped; at which time, you will remain standing on the treadmill platform in a relaxed position but neither leaning nor resting

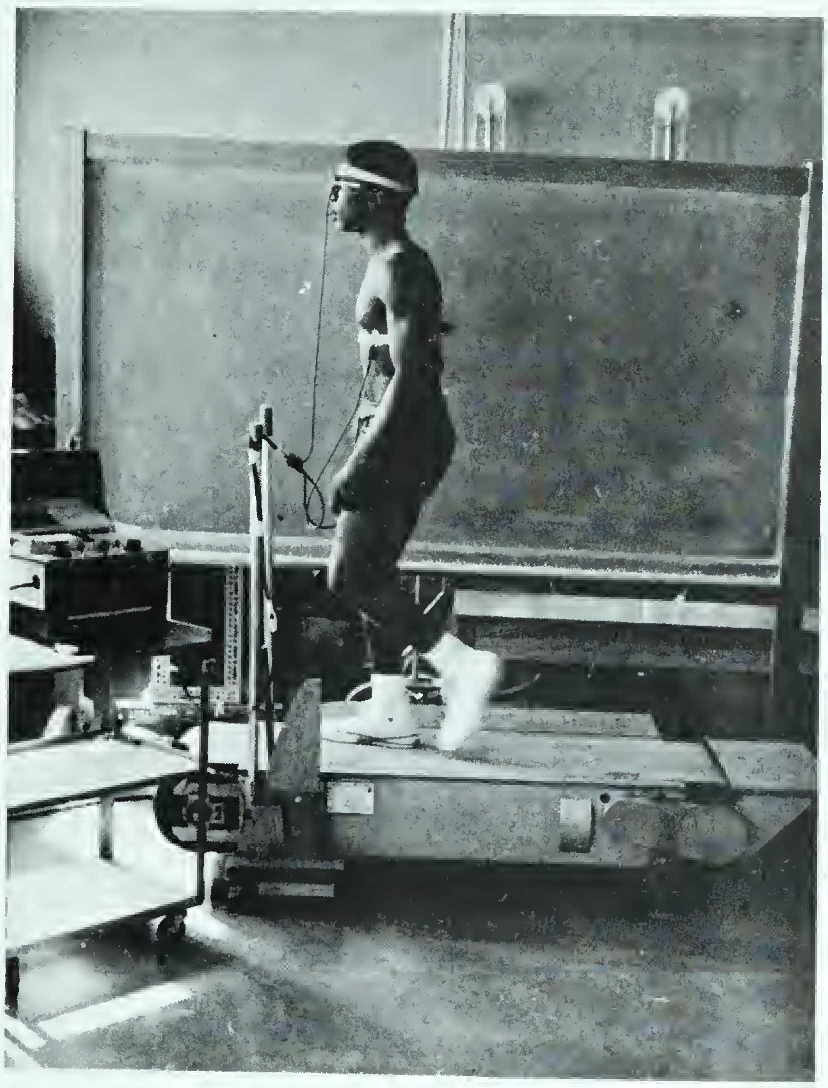

FIGURE I.

Balke Treadmill Test Apparatus
(Horizontal Platform)

FIGURE II.

Balke Treadmill Test Apparatus
(Raised Platform)

on or against any of the apparatus.

c) At no time during the test or during the recovery period will you speak unless you are asked a specific question.

d) When the recovery period is over, you will be asked to step down from the treadmill, indicating that the test is fully completed.

e) The test will commence in 30 seconds."

2. The Terminal Step Test. This test consisted of stepping up to and down from a 20 inch bench, 30 times per minute in cadence with a metronome set at 120 beats per minute. When the heart rate reached 180 beats per minute, the test was terminated.

Test Instructions. Standardized test instructions were given to each subject:

"a) You are to step up to and down from the bench in time with the metronome. You may step up with either foot first, or change during the exercise at any time as long as you maintain the rhythm.

b) When you step up onto the bench, you will extend your hips and knees completely. By doing so, you will break the photo-electric circuit adjusted to your height and a buzzer will sound. Each time the buzzer sounds, a cumulative counter will record your step-up.

c) You will continue the exercise at the set cadence until you are instructed to stop; at which time, you will stand in front of the bench in a

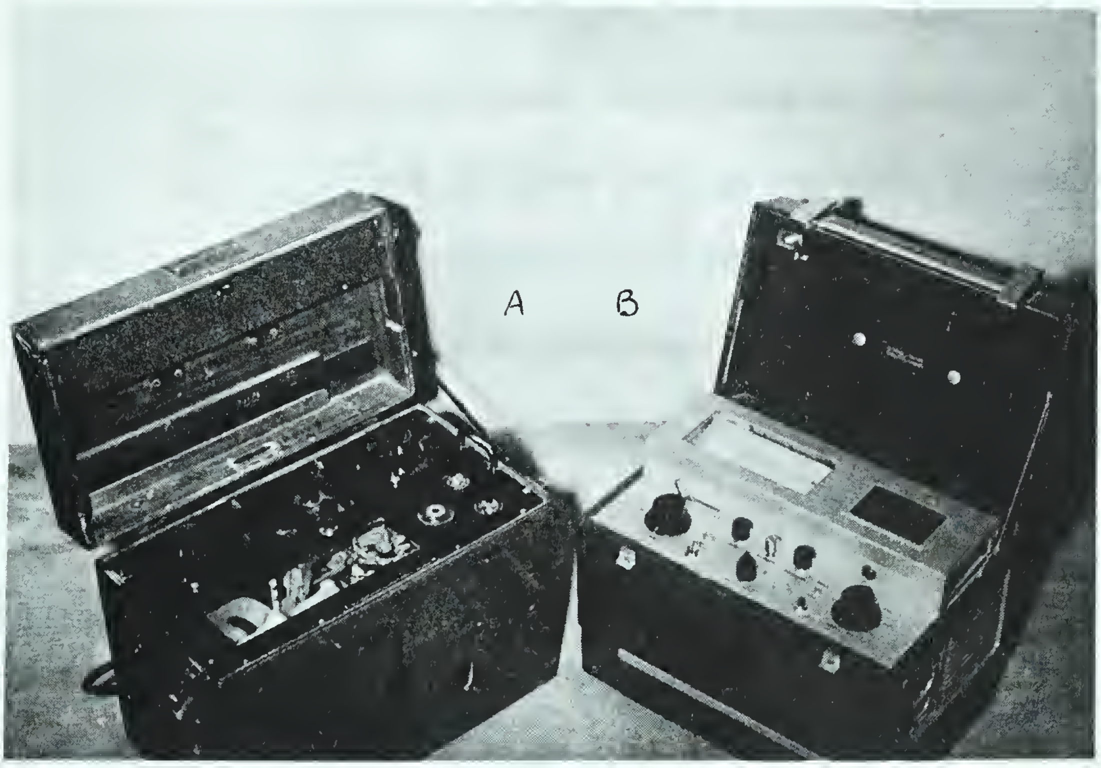

FIGURE III. Sanborn Electrocardiographs
A-Model 51
B-Model 100

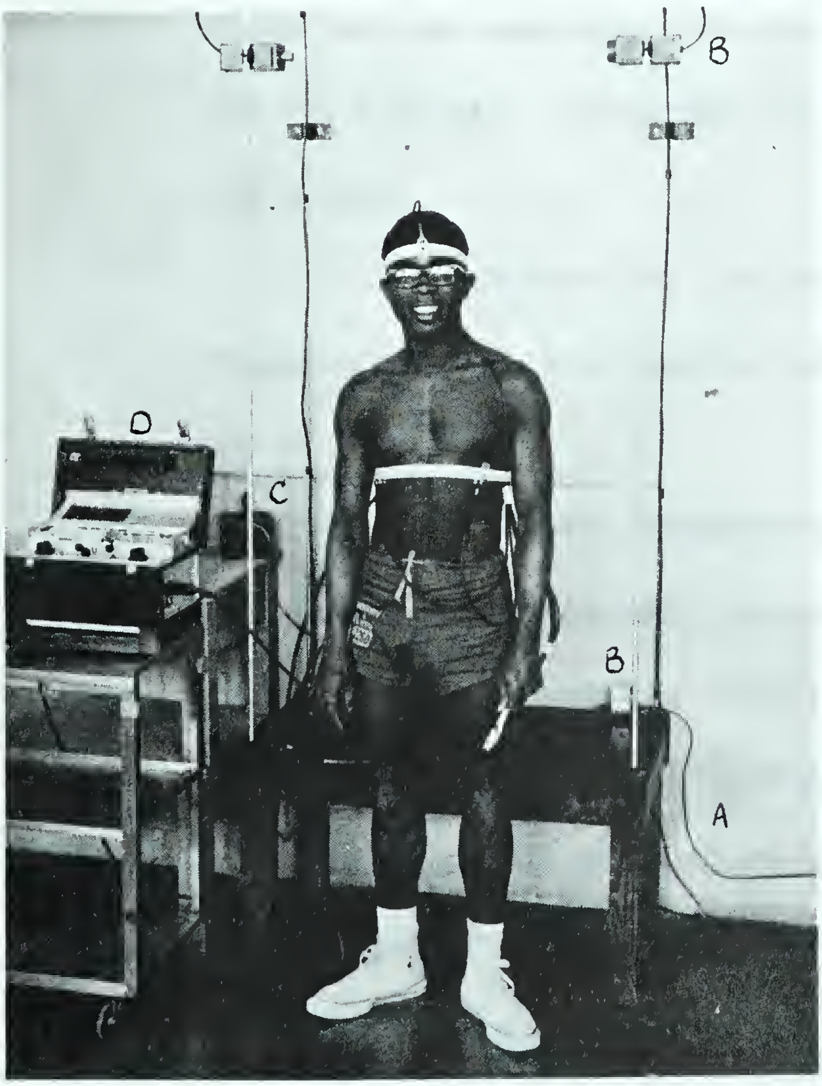

FIGURE IV. Terminal Step Test Apparatus

A - Stepping Bench
B - Photo-Electric Counter & Buzzer System
C - Metronome
D - Sanborn Viso-Cardiette With Surface Electrode Attachments

relaxed position but neither leaning nor resting on or against any of the apparatus.

d) At no time during the test or during the recovery period will you speak unless you are asked a specific question.

e) You will commence when you have the metronome rhythm."

Experimental Design.

Phase One. Subjects that were initially selected were asked to report to the physical education laboratory in T-shirt, gym shorts and running shoes on five selected days at similar times, chosen at their convenience.

Day One. The purpose of the subjects' initial visit was to take some of the less time-consuming measurements and to acquaint them with the procedure to be followed during the study.

When the subject reported to the laboratory, his weight, height, leg length and three bilateral strength measurements were taken.

Upon completion of these measurements, the subject was shown the treadmill, the stepping bench and the electrocardiograph equipment and how they were to be used.

Although walking and stepping are daily normal activities, each subject was given a short training session on the treadmill and the stepping bench to remove any possible future apprehension that might arise, especially in the former (5, 6, 7).

With the subject standing on the level treadmill

platform, the surface electrodes were strapped in place and were connected to the leads of the electrocardiograph. The subject was told to begin walking in a normal manner towards the front of the treadmill as soon as the motor was started. Upon starting the treadmill motor at a slow speed, speed and slope were gradually increased, so that by the end of the training session (5 minutes), the subject had been walking at 91.2 $\pm$ 2.7 metres per minute for the last two minutes with the grade increased 1 percent per minute. At the end of the fifth minute, the treadmill was stopped, the platform was lowered and the electrode leads were disconnected.

With the surface electrodes still strapped in place, the subject was asked to sit quietly for ten minutes.

At the end of this rest period, the electrode leads were once again connected, with the subject standing in front of the stepping bench. The metronome was started and the subject was instructed to begin stepping up onto and down from the bench when he had attained the metronome rhythm. He was also instructed to try and break the photo-electric beam above the bench which was adjusted to his height. At the end of the third minute, the subject was told to stop and the electrode leads were disconnected.

While removing the electrode straps, the subject was informed that his initial testing and training session was completed, reminded of his next session and thanked for his cooperation and time.

Days Two to Five. Previous to their second session at the laboratory, the subjects were numbered. Each odd

numbered subject was given the step test on the 2nd day, the treadmill test on the 3rd day, the step test on the 4th day and the treadmill test on the 5th day. The even numbered subjects were given a directly opposite alternating test arrangement.

Upon reporting to the laboratory, the subject was asked to remove his T-shirt and the surface electrodes were strapped into place. The subject was then asked to sit quietly for ten minutes. During this period, the subject was told the standardized test instructions, as outlined previously with regard to his specific test for that day, either the Balke Treadmill test or the Terminal Step test.

At the end of the rest period, the subject walked to the respective testing apparatus where the surface electrodes were connected to the leads of the electrocardiograph. The pre-exercise standing pulse rate was taken in the last five seconds of each half minute for two minutes. Shortly thereafter, the respective test began.

During the test, the exercise pulse rate was taken in the last five seconds of each half minute of performance until a heart rate of 170 was attained; then heart rate readings were taken every ten to fifteen seconds.

When the heart rate was 180 beats per minute or had reached a stationary level slightly below 180 beats per minute for three similar consecutive readings on the electrocardiogram, the test was terminated.

The subject then stood for seven minutes, as instructed, while the recovery pulse rate was taken during the last five seconds for each half minute for seven minutes.

When the recovery period was finished, the electrode leads were disconnected, the electrode straps were removed, and the testing session was completed.

The same procedure was followed through testing sessions two to five inclusive until each subject had completed the Balke Treadmill test and the Terminal Step test twice.

Phase Two. Forty-five subjects, not previously employed, were randomly selected from the freshmen classes in February, March and April of 1964. Each subject was asked to report to the physical education laboratory on two separate occasions at his own convenience.

During session one, each subject performed a Terminal Step test and had his height, weight and age recorded; while in session two, he performed the Balke Treadmill test.

Testing methods utilized in phase two were the same as outlined in phase one with a few procedural changes. These changes were:

1. A one minute training session followed by a ten minute sitting rest was given before the Terminal Step test.

2. During the Terminal Step test, the photo-electric buzzer system was not employed in order to make the test more practical.

3. Each subject was given a three minute training session on the treadmill following the Terminal Step test.

4. Pre-exercise and post-exercise heart rates were not recorded during phase two for the Balke Treadmill test.

REFERENCES

1. Dixon, W. J., Massey, F. M., Introduction to Statistical Analysis, 2nd ed., Toronto: McGraw-Hill Book Company, Inc., 1957, pp. 366-70.

2. Clarke, H. H., Clarke, D., Developmental and Adapted Physical Education, Englewood Cliffs: Prentice-Hall, Inc., 1963, pp. 73-96.

3. Bobbert, A. C., "Physiological Comparison of Three Types of Ergometry," Journal of Applied Physiology, vol. 15 (Nov. 1960), pp. 1007-14.

4. Balke, B., Clark, R. T., "Cardio-Pulmonary and Metabolic Effects of Physical Training," Health and Fitness in the Modern World, Athletic Institute, 1961, pp. 82-7.

5. Alexander, J. F., Fraser, R. S., Cavero, C., "An Evaluation of the 5BX Program of Exercise by a Treadmill Performance Test," Journal of the Canadian Association for Health, Physical Education and Recreation, vol. 28 (Feb. - Mar. 1962), p. 21.

6. Hunsicker, P. A., "A Validation of Cardiovascular Tests by Cardiac Output Measurements," Doctoral Thesis, University of Illinois, 1950, Microcard.

7. Balke, B., Ware, R. W., "An Experimental Study of Physical Fitness of Air Force Personnel," United States Armed Forces Medical Journal, vol. 10 (June 1959), pp. 675-88.

CHAPTER IV

RESULTS AND DISCUSSION

Results.

Reliability of Measurements. The Pearson Product-Moment method (1:112) was used to determine the test-retest reliability coefficients for all the measurements used in the study. The obtained reliability coefficients along with their respective means and variances for test one and the retest appear in Tables I, II and III.

TABLE I

TEST-RETEST RELIABILITY COEFFICIENTS, MEANS AND VARIANCES (N = 30)

ANTHROPOMETRIC AND STRENGTH MEASURES	RELIABILITY COEFFICIENT	TEST ONE MEAN	TEST ONE VARIANCE	RETEST MEAN	RETEST VARIANCE
WEIGHT (kgs)	0.998*	66.71	65.32	66.77	65.43
HEIGHT (m)	0.999*	1.73	0.004	1.73	0.004
LEG LENGTH (m)	0.998*	0.89	0.003	0.89	0.003
PLANTAR FLEXION (kgs)	0.848*	105.48	379.17	107.24	453.55
KNEE EXTENSION (kgs)	0.867*	109.13	640.51	106.03	605.04
HIP EXTENSION (kgs)	0.843*	72.95	244.27	74.30	320.77

* $r \geq 0.463$; Statistically significant at the .01 level of confidence.

The reliability coefficients of Table I were calculated using the mean of trials for test one to the mean of trials for test two. Each of these reliability coefficients was significantly different from zero at the .01 level of confidence, (N = 30).

TABLE II

TEST-RETEST RELIABILITY COEFFICIENTS, MEANS AND VARIANCES (N = 30)

STEP TEST MEASURES	RELIABILITY COEFFICIENT	TEST ONE MEAN	TEST ONE VARIANCE	RETEST MEAN	RETEST VARIANCE
PERFORMANCE TIME (min.)	0.988*	2.12	0.61	2.16	0.61
PRE-EXERCISE STANDING HEART RATE (beats/min.)					
0.5 MIN.	0.501*	91.37	246.86	86.50	227.03
1.0 MIN.	0.616*	90.87	236.03	88.80	229.62
1.5 MIN.	0.592*	90.80	260.52	90.40	252.72
2.0 MIN.	0.657*	91.20	173.00	92.13	254.76
POST-EXERCISE STANDING HEART RATE (beats/min.)					
0.5 MIN.	0.372**	151.67	103.00	152.10	46.52
1.0 MIN.	0.693*	137.00	138.89	136.20	134.66
1.5 MIN.	0.582*	127.80	185.89	125.76	124.72
2.0 MIN.	0.341	122.48	134.10	120.80	171.69
2.5 MIN.	0.646*	118.46	133.93	114.63	165.41
3.0 MIN.	0.583*	112.96	168.03	112.50	172.00
3.5 MIN.	0.456**	111.13	187.17	110.16	139.24
4.0 MIN.	0.771*	110.00	171.17	108.60	164.66
4.5 MIN.	0.752*	107.30	158.76	108.06	113.59
5.0 MIN.	0.729*	108.86	154.41	106.73	142.62
5.5 MIN.	0.657*	108.73	146.89	107.03	142.76
6.0 MIN.	0.704*	107.83	125.45	107.13	133.31
6.5 MIN.	0.685*	108.03	158.52	105.96	112.10
7.0 MIN.	0.736*	105.77	171.34	104.77	140.17

* $r \geq 0.463$; Statistically significant at the .01 level of confidence.
** $r \geq 0.361$; Statistically significant at the .05 level of confidence.

The reliability coefficients for the Terminal Step test (Table II) and for the Balke Treadmill test (Table III) measures were calculated using the test-retest method. Each of these reliability coefficients was significantly different from zero at the .01 or .05 level of confidence as indicated in the tables; with three exceptions, Step test post-exercise standing heart rate - 2.0 min., Treadmill test pre-exercise standing heart rate - 1.5 min. and Treadmill test post-exercise standing heart rate - 2.0 min. which

were not statistically significant (N = 30).

TABLE III

TEST-RETEST RELIABILITY COEFFICIENTS,
MEANS AND VARIANCES (N = 30)

TREADMILL TEST MEASURES	RELIABILITY COEFFICIENT	TEST ONE MEAN	TEST ONE VARIANCE	RETEST MEAN	RETEST VARIANCE
PERFORMANCE TIME (min.)	0.975*	15.74	6.04	15.85	5.80
PRE-EXERCISE STANDING HEART RATE (beats/min.)					
0.5 MIN.	0.644*	87.20	185.14	88.03	130.24
1.0 MIN.	0.482*	89.00	238.83	88.03	89.00
1.5 MIN.	0.349	89.43	211.31	88.30	116.89
2.0 MIN.	0.495*	88.43	185.76	87.90	125.89
POST-EXERCISE STANDING HEART RATE (beats/min.)					
0.5 MIN.	0.419**	150.03	54.03	151.10	49.41
1.0 MIN.	0.586*	135.67	105.55	133.57	71.83
1.5 MIN.	0.452**	128.73	78.34	125.43	92.59
2.0 MIN.	0.309	122.83	74.00	120.23	76.86
2.5 MIN.	0.562*	120.43	99.27	118.77	69.28
3.0 MIN.	0.480*	117.80	96.38	114.70	125.45
3.5 MIN.	0.471*	116.10	99.28	115.40	72.52
4.0 MIN.	0.660*	115.47	86.83	113.60	67.62
4.5 MIN.	0.616*	114.13	53.97	112.47	85.17
5.0 MIN.	0.756*	112.63	77.00	110.77	63.83
5.5 MIN.	0.636*	113.17	72.00	109.10	85.62
6.0 MIN.	0.634*	111.63	75.69	109.77	77.76
6.5 MIN.	0.532*	111.23	90.59	108.50	95.62
7.0 MIN.	0.718*	110.87	106.07	107.90	114.72

* $r \geq 0.463$; Statistically significant at the .01 level of confidence.
** $r \geq 0.361$; Statistically significant at the .05 level of confidence.

Descriptive Statistics for Sample One. The descriptive statistics for observations made on sample one (45 subjects) of this study are summarized in Table IV. The data for sample one observations are presented in detail in Appendix C.

The means and standard deviations in Table IV were procured through the use of an I.B.M. - 1620 Electronic Computer - program # 1620-013

(2).

The subjects were in the age range of 17 to 27 years, with a mean age of 18.71 years ± 1.56. The mean total body weight, erect body height and standling leg length were 69.02 ± 9.27 kilograms, 1.75 ± 0.067 metres and 0.897 ± 0.046 metres respectively. The mean combined strength of the plantar flexors, knee and hip extensors was 592.88 ± 101.38 kilograms.

The mean performance times for the two work capacity tests were 16.03 ± 2.78 minutes for the Balke Treadmill test and 2.17 ± 0.90 for the Terminal Step test.

The means for barometric pressure and temperature during testing were 705.87 ± 3.03 millimeters and 20.20 ± 1.99 degrees centigrade respectively.

TABLE IV

MEANS, STANDARD DEVIATIONS AND RANGES
OF OBSERVATIONS MADE ON SAMPLE ONE
(N = 45)

VARIABLE	MEAN	STANDARD DEVIATION	RANGE
AGE (yrs.)	18.71	1.56	17 - 27
WEIGHT (kgs.)	69.02	9.27	47.55 - 87.77
HEIGHT (m.)	1.75	0.067	1.57 - 1.91
LEG LENGTH (m.)	0.897	0.046	0.75 - 1.04
LEG LENGTH/HEIGHT	0.51	0.013	0.479 - 0.543
STRENGTH (kgs.)			
LEFT PLANTAR FLEXION	106.98	20.16	65.54 - 159.89
RIGHT PLANTAR FLEXION	107.47	22.44	66.23 - 151.05
LEFT KNEE EXTENSION	111.41	25.52	58.40 - 161.93
RIGHT KNEE EXTENSION	113.06	24.80	54.99 - 158.53
LEFT HIP EXTENSION	74.24	15.66	36.51 - 107.05
RIGHT HIP EXTENSION	79.95	17.91	23.81 - 121.56
COMBINED STRENGTH	592.88	101.38	375.92 - 799.69
TREADMILL HEART RATES (beats/min.)			
PRE-EXERCISE (beats/min.)			
0.5 MIN.	89.04	12.33	67 - 114
1.0 MIN.	88.42	11.08	66 - 109

TABLE IV continued....

VARIABLE	MEAN	STANDARD DEVIATION	RANGE
1.5 MIN.	89.51	12.21	67 - 118
2.0 MIN.	88.44	11.62	65 - 120
EXERCISE			
0.5 MIN.	117.44	9.66	99 - 142
1.0 MIN.	114.22	10.35	84 - 144
1.5 MIN.	115.76	10.20	86 - 144
2.0 MIN.	115.29	10.92	87 - 144
2.5 MIN.	116.49	9.85	87 - 142
3.0 MIN.	117.18	10.50	88 - 142
3.5 MIN.	118.80	9.42	92 - 140
4.0 MIN.	120.18	10.33	88 - 140
4.5 MIN.	122.33	10.41	94 - 146
5.0 MIN.	124.42	9.98	97 - 147
5.5 MIN.	126.49	9.50	98 - 144
6.0 MIN.	127.22	11.52	88 - 149
6.5 MIN.	130.84	10.57	103 - 152
7.0 MIN.	132.71	11.16	104 - 155
7.5 MIN.	136.29	10.28	109 - 156
8.0 MIN.	138.73	11.51	109 - 157
8.5 MIN.	141.73	10.78	112 - 160
9.0 MIN.	143.84	11.25	113 - 166
9.5 MIN.	146.67	11.93	118 - 169
10.0 MIN.	149.04	12.06	117 - 171
10.5 MIN.	151.78	11.68	124 - 173
11.0 MIN.	153.84	12.21	124 - 173
11.5 MIN.	156.93	12.24	125 - 180
POST-EXERCISE			
0.5 MIN.	150.58	7.77	133 - 166
1.0 MIN.	133.71	7.97	118 - 155
1.5 MIN.	125.89	9.07	103 - 149
2.0 MIN.	121.00	9.22	104 - 144
2.5 MIN.	119.58	8.33	103 - 137
3.0 MIN.	116.31	9.66	94 - 137
3.5 MIN.	113.87	8.93	94 - 135
4.0 MIN.	113.91	8.52	93 - 133
4.5 MIN.	112.38	8.81	95 - 130
5.0 MIN.	111.47	8.11	94 - 127
5.5 MIN.	109.53	9.65	87 - 128
6.0 MIN.	109.09	8.91	90 - 127
6.5 MIN.	108.58	9.44	84 - 128
7.0 MIN.	108.00	10.09	87 - 128
TREADMILL PERFORMANCE TIME (min.)	16.03	2.78	11.50 - 23.55

TABLE IV continued....

VARIABLE	MEAN	STANDARD DEVIATION	RANGE
TREADMILL EXTERNAL WORK (mkg./min.)	971.14	185.05	563.70 - 1360.44
STEP TEST HEART RATES (beats/min.)			
PRE-EXERCISE			
0.5 MIN.	88.89	14.19	57 - 120
1.0 MIN.	90.64	14.76	65 - 124
1.5 MIN.	91.04	14.80	53 - 124
2.0 MIN.	92.78	15.53	50 - 130
EXERCISE			
0.5 MIN.	152.62	11.95	129 - 173
1.0 MIN.	165.13	9.39	144 - 180
POST-EXERCISE			
0.5 MIN.	153.16	7.85	140 - 170
1.0 MIN.	136.98	10.97	117 - 155
1.5 MIN.	125.80	10.83	105 - 149
2.0 MIN.	120.49	12.64	83 - 144
2.5 MIN.	114.78	12.28	92 - 140
3.0 MIN.	113.09	12.64	83 - 142
3.5 MIN.	110.93	11.91	88 - 135
4.0 MIN.	108.80	11.74	77 - 133
4.5 MIN.	108.22	10.44	88 - 130
5.0 MIN.	107.80	10.85	79 - 130
5.5 MIN.	107.44	11.36	73 - 128
6.0 MIN.	107.00	10.92	83 - 130
6.5 MIN.	106.87	10.59	83 - 130
7.0 MIN.	105.62	10.94	76 - 130
STEP TEST PERFORMANCE TIME (min.)	2.17	0.90	0.89 - 4.20
STEP TEST EXTERNAL WORK (mkg.)	2243.26	931.72	864.33 - 4511.28
BAROMETRIC PRESSURE (MM)	705.87	3.03	700 - 714
TEMPERATURE (°C)	20.20	1.99	15 - 24

Means, standard deviations and ranges of heart rates for the Balke Treadmill test and Terminal Step test are also presented in Table IV. Their calculated external work are, as well, presented.

Correlation Analysis. An intercorrelation matrix of the seventy-seven variables utilized in the study - obtained through the University of Alberta Computing Centre - program #1620-013 (2) - is presented in Appendix C. The coefficients of correlation that are directly concerned with the purpose of this investigation have been extracted from the aforementioned intercorrelation matrix and are presented in Tables V, VI and VII.

TABLE V

COEFFICIENTS OF CORRELATION OF AGE, ANTHROPOMETRICAL AND PHYSIOLOGICAL MEASUREMENTS TO BALKE TREADMILL TEST PERFORMANCE TIME BASED ON SAMPLE ONE (N = 45)

VARIABLE	CORRELATION COEFFICIENT	CORRELATION COEFFICIENT SUARED x 100 (%)
AGE	-0.004	0.002
WEIGHT	-0.241	5.81
HEIGHT	0.148	2.19
LEG LENGTH	0.198	3.92
LEG LENGTH/HEIGHT	0.171	2.92
STRENGTH		
LEFT PLANTAR FLEXION	-0.104	1.08
RIGHT PLANTAR FLEXION	-0.037	0.14
LEFT KNEE EXTENSION	-0.143	2.04
RIGHT KNEE EXTENSION	-0.135	1.82
LEFT HIP EXTENSION	-0.155	2.40
RIGHT HIP EXTENSION	-0.172	2.96
COMBINED STRENGTH	-0.155	2.40
TREADMILL HEART RATES		
PRE-EXERCISE		
0.5 MIN.	-0.247	6.10
1.0 MIN.	-0.292	8.53
1.5 MIN.	-0.194	3.76
2.0 MIN.	-0.295**	8.70
EXERCISE		
0.5 MIN.	-0.470*	22.09
1.0 MIN.	-0.529*	27.98
1.5 MIN.	-0.524*	27.46
2.0 MIN.	-0.633*	40.07
2.5 MIN.	-0.614*	37.70
3.0 MIN.	-0.622*	38.69
3.5 MIN.	-0.602*	36.24

TABLE V continued....

VARIABLE	CORRELATION COEFFICIENT	CORRELATION COEFFICIENT SQUARED x 100 (%)
4.0 MIN.	-0.683*	46.65
4.5 MIN.	-0.654*	42.77
5.0 MIN.	-0.672*	45.16
5.5 MIN.	-0.675*	45.56
6.0 MIN.	-0.668*	44.62
6.5 MIN.	-0.718*	51.55
7.0 MIN.	-0.770*	59.29
7.5 MIN.	-0.792*	62.73
8.0 MIN.	-0.802*	64.32
8.5 MIN.	-0.817*	66.75
9.0 MIN.	-0.818*	66.91
9.5 MIN.	-0.830*	68.89
10.0 MIN.	-0.877*	76.91
10.5 MIN.	-0.885*	78.32
11.0 MIN.	-0.872*	76.04
11.5 MIN.	-0.897*	80.46
POST-EXERCISE		
0.5 MIN.	0.001	0.00
1.0 MIN.	0.046	0.21
1.5 MIN.	-0.002	0.00
2.0 MIN.	-0.053	0.28
2.5 MIN.	-0.243	5.90
3.0 MIN.	-0.063	0.40
3.5 MIN.	-0.098	0.96
4.0 MIN.	-0.253	6.40
4.5 MIN.	-0.222	4.93
5.0 MIN.	-0.041	0.17
5.5 MIN.	-0.071	0.50
6.0 MIN.	-0.174	3.03
6.5 MIN.	-0.003	0.00
7.0 MIN.	-0.096	0.92
TREADMILL EXTERNAL WORK	0.749*	56.10

* $r \geq 0.380$; Statistically significant at the .01 level of confidence.
** $r \geq 0.295$; Statistically significant at the .05 level of confidence.

The coefficients of correlation of age, anthropometrical and physiological measures to Balke Treadmill test performance time are shown in Table V.

Age (-0.004), weight (-0.241), height (.148), leg length (0.198) and leg length-height ratio (0.171) were not significantly correlated with

performance time in the Balke Treadmill test.

Bi-lateral strength of the plantar flexors (-0.104 and -0.037), of the knee extensors (-0.143 and -0.135) and of the hip extensors (-0.155 and -0.172) revealed no significant correlations with performance time in the Balke Treadmill test. The correlation coefficient obtained for the relationship of the combined strengths to performance time was -0.155 which was not statistically significant.

Treadmill test pre-exercise heart rates at 0.5, 1.0 and 1.5 minutes were also not significantly correlated with performance time, yielding coefficients of -0.247, -0.292 and -0.194 respectively. Pre-exercise heart rate at 2.0 minutes correlated -0.295 with performance time which is of borderline significance at the .05 level of confidence.

Treadmill test exercise heart rates were correlated with performance time at each level, yielding coefficients that were all statistically significant at the .01 level of confidence. These coefficients of correlation ranged from -0.470 at 0.5 minutes to -0.897 at 11.5 minutes revealing an increasing correlation coefficient at each level.

Treadmill test post-exercise heart rates were not correlated significantly with performance time, yielding fluctuating correlation coefficients ranging from 0.046 at 1.0 minutes to -0.253 at 4.0 minutes.

The correlation coefficient obtained for the relationship of treadmill external work to performance time in the Balke test was 0.749, which was statistically significant at the .01 level of confidence.

TABLE VI

COEFFICIENTS OF CORRELATION OF AGE,
ANTHROPOMETRICAL AND PHYSIOLOGICAL MEASUREMENTS
TO TERMINAL STEP TEST PERFORMANCE TIME BASED ON
SAMPLE ONE (N = 45)

VARIABLE	CORRELATION COEFFICIENT	CORRELATION COEFFICIENT SQUARED x 100 (%)
AGE	-0.072	0.52
WEIGHT	-0.234	5.48
HEIGHT	-0.124	1.54
LEG LENGTH	-0.039	0.15
LEG LENGTH/HEIGHT	0.094	0.88
STRENGTH		
LEFT PLANTAR FLEXION	-0.167	2.79
RIGHT PLANTAR FLEXION	-0.083	0.69
LEFT KNEE EXTENSION	-0.190	3.61
RIGHT KNEE EXTENSION	-0.118	1.39
LEFT HIP EXTENSION	-0.148	2.19
RIGHT HIP EXTENSION	-0.264	6.97
COMBINED STRENGTH	-0.202	4.08
STEP TEST HEART RATES		
PRE-EXERCISE		
0.5 MIN.	-0.325**	10.56
1.0 MIN.	-0.303**	9.18
1.5 MIN.	-0.285	8.12
2.0 MIN.	-0.402*	16.16
EXERCISE		
0.5 MIN.	-0.709*	50.27
1.0 MIN.	-0.850*	72.25
POST-EXERCISE		
0.5 MIN.	-0.106	1.12
1.0 MIN.	0.013	0.02
1.5 MIN.	0.115	1.32
2.0 MIN.	0.093	0.86
2.5 MIN.	0.096	0.92
3.0 MIN.	0.101	1.02
3.5 MIN.	-0.002	0.00
4.0 MIN.	-0.017	0.03
4.5 MIN.	0.044	0.19
5.0 MIN.	-0.021	0.04
5.5 MIN.	0.019	0.04
6.0 MIN.	0.028	0.08
6.5 MIN.	-0.038	0.14
7.0 MIN.	-0.075	0.56

TABLE VI continued....

VARIABLE	CORRELATION COEFFICIENT	CORRELATION COEFFICIENT SQUARED x 100 (%)
STEP TEST EXTERNAL WORK	0.956*	91.39

* $r \geqslant 0.380$; Statistically significant at the .01 level of confidence.
** $r \geqslant 0.295$; Statistically significant at the .05 level of confidence.

The coefficients of correlation of age, anthropometrical and physiological measures to Terminal Step test performance time are presented in Table VI.

Age (-0.072), weight (-0.234), height (-0.124), leg length (-0.039) and leg length/height ratio (0.094) were not significantly correlated with performance time in the Terminal Step test.

Bi-lateral strength of the plantar flexors (-0.167 and -0.083), of the knee extensors (-0.190 and -0.118) and of the hip extensors (-0.148 and -0.264) revealed no significant correlations with performance time in the Terminal Step test. The correlation coefficient obtained for the relationship of the combined strengths to performance time was -0.202 which was not statistically significant.

Step test pre-exercise heart rates at 0.5 and 1.0 minutes were significantly correlated with performance time at the .05 level of confidence, yielding coefficients of -0.325 and -0.303 respectively. Correlation coefficients obtained for the relationship of pre-exercise heart rates at 1.5 and 2.0 minutes to performance time were -0.285 and -0.402 respectively. The latter of these two was statistically significant at the .01 level of confidence.

Step test exercise heart rates were correlated with performance time at each level yielding coefficients of -0.709 and -0.850 which were statistically significant at the .01 level of confidence.

Step test post-exercise heart rates were not correlated significantly with performance time at any level. The correlation coefficients were of a fluctuating magnitude and ranged from -0.106 at 0.5 minutes to 0.115 at 1.5 minutes.

The correlation coefficient obtained for the relationship of step test external work to performance time in the Terminal Step test was 0.956 which was statistically significant at the .01 level of confidence.

TABLE VII

COEFFICIENTS OF CORRELATION OF SPECIFIC TERMINAL STEP TEST PARAMETERS TO BALKE TREADMILL TEST PERFORMANCE TIME BASED ON SAMPLE ONE
(N = 45)

VARIABLE	CORRELATION COEFFICIENT	CORRELATION COEFFICIENT SQUARED x 100 (%)
STEP TEST HEART RATES		
EXERCISE		
0.5 MIN.	-0.512*	26.21
1.0 MIN.	-0.643*	41.34
POST-EXERCISE		
0.5 MIN.	-0.265	7.02
1.0 MIN.	-0.132	1.74
1.5 MIN.	-0.061	0.37
2.0 MIN.	-0.043	0.18
2.5 MIN.	-0.123	1.51
3.0 MIN.	-0.082	0.67
3.5 MIN.	-0.154	2.37
4.0 MIN.	-0.154	2.37
4.5 MIN.	-0.114	1.30
5.0 MIN.	-0.159	2.53
5.5 MIN.	-0.058	0.34
6.0 MIN.	-0.119	1.42
6.5 MIN.	-0.155	2.40
7.0 MIN.	-0.231	5.34
STEP TEST EXTERNAL WORK	0.711*	50.55
STEP TEST PERFORMANCE TIME	0.776*	60.22

* $r \geq 0.380$; Statistically significant at the .01 level of confidence.

The coefficients of correlation of specific Terminal Step test parameters to Balke Treadmill test performance time are shown in Table VII.

Terminal Step test exercise heart rates at 0.5 and 1.0 minutes correlated -0.512 and -0.643 respectively with performance time in the Balke test, both of which were statistically significant at the .01 level of confidence.

Terminal Step test post-exercise heart rates were not significantly correlated with performance time in the Balke test at any level. Fluctuating correlations coefficients were procured and ranged from -0.043 at 2.0 minutes to -0.265 at 0.5 minutes.

The correlation coefficient obtained for the relationship of Terminal Step test external work to performance time in the Balke test was 0.711, and of Terminal Step test performance time to performance time in the Balke test was 0.776, both of which were statistically significant at the .01 level of confidence.

The coefficients of correlation in column two of Tables V, VI and VII have been squared and multiplied by 100 - percentage form - for future reference in the discussion section of this chapter.

Multiple Regression Analysis. The "Stepwise Procedure for Multiple Regression," as described by Efroymson (3), was used to determine the relative size of the contribution of each specific Terminal Step test parameter in Table VII to the criterion - performance time in the Balke Treadmill test. The results of this multiple regression analysis are presented in Tables VIII and IX and their procurement obtained through the University of Alberta Computing Centre - program #1620-019 (4).

In column one of Table VIII, the independent variables have been arranged according to the order of their inclusion in the final multiple regression equation. In the second to fifth columns inclusive, the t -

values for the beta coefficients are presented. In column six, the percentage of interpersonal variance in Balke Treadmill test performance time accounted for by the inclusion of each independent variable into the multiple regression equation is shown.

TABLE VIII

RELATIONSHIP BETWEEN BALKE TREADMILL TEST PERFORMANCE TIME AND SPECIFIC TERMINAL STEP TEST PARAMETERS (MULTIPLE REGRESSION ANALYSIS N = 45)

VARIABLE - SPECIFIC TERMINAL STEP TEST PARAMETERS	t - VALUE FOR BETA COEFFICIENTS (df. = N-n-1)				PERCENTAGE OF TOTAL VARIANCE ACCOUNTED FOR BY REGRESSION
PERFORMANCE TIME (min.) - X_{76}	8.07*	8.57*	8.95*	8.17*	60.24
POST-EXERCISE HEART RATE AT 2.5 min. - X_{66}		-2.14***	-2.75**	-1.59	3.93
POST-EXERCISE HEART RATE AT 5.5 min. - X_{72}			1.83	2.45***	2.72
POST-EXERCISE HEART RATE AT 7.0 min. - X_{75}				-1.59	1.98

* Statistically significant at the .001 level of confidence.
** Statistically significant at the .01 level of confidence.
*** Statistically significant at the .05 level of confidence.

Terminal Step test performance time accounted for the largest proportion of the variance, 60.24%, in Balke Treadmill test performance time. Terminal Step test post-exercise heart rates at 2.5, 5.5 and 7.0 minutes accounted for 3.93, 2.72 and 1.98 percent respectively, of the remaining variation in performance time of the Balke Treadmill test.

In regard to the t - values for the beta coefficients of the independent variables, they are changing values. This is due to the fact that as each independent variable is introduced into the multiple regres-

sion equation in order of importance, the beta weight (see Table IX) and their corresponding standard errors change. The indication of statistical significance of these t - values is reported in Table VIII.

The relationship between performance time in the Balke Treadmill test and specific parameters of the Terminal Step test is presented in Table IX in the form of beta weights, constants, standard errors of estimate and cumulative percentages of the total variance accounted for by regression.

The resultant equations utilized for the prediction of performance time in the Balke Treadmill test and derived from Table IX were:

A. $\hat{Y}_1 = 2.394\ X_{76} + 10.845 \pm 1.775$

B. $\hat{Y}_2 = 2.453\ X_{76} - 0.0452\ X_{66} + 15.901 \pm 1.705$

C. $\hat{Y}_3 = 2.508\ X_{76} - 0.1009\ X_{66} + 0.0724\ X_2 + 14.412 \pm 1.659$

D. $\hat{Y}_4 = 2.365\ X_{76} - 0.0668\ X_{66} + 0.1239\ X_{72} - 0.0951\ X_{75} + 15.302 \pm 1.629$

Where: X_{76} = Terminal Step Test performance time in minutes.

X_{66} = Terminal Step Test post-exercise heart rate at 2.5 minutes.

X_{72} = Terminal Step Test post-exercise heart rate at 5.5 minutes.

X_{75} = Terminal Step Test post-exercise heart rate at 7.0 minutes.

Although eighteen specific Terminal Step test parameters (see Table VII) were introduced into the multiple regression analysis, only the first four prediction equations were selected and employed in this investigation. The reasons for this decision were twofold: 1. The practicability and application of the equations, and 2. the inclusion of other variables into the regression equations would result in a greater range of prediction errors caused by an increasing standard error of estimate and by an increasing error mean square in the analysis of variance of the indepen-

TABLE IX

RELATIONSHIP BETWEEN BALKE TREADMILL TEST PERFORMANCE TIME AND SPECIFIC TERMINAL STEP TEST PARAMETERS (MULTIPLE REGRESSION ANALYSIS, N = 45)

	BETA WEIGHT FOR SPECIFIC TERMINAL STEP TEST PARAMETERS POST-EXERCISE HEART RATES					
PERFORMANCE TIME X_{76}	2.5 Min. X_{66}	5.5 Min. X_{72}	7.0 Min. X_{75}	CONSTANT	STANDARD ERROR OF ESTIMATE (Min.)	CUMULATIVE PERCENTAGE OF TOTAL VARIANCE ACCOUNTED FOR BY REGRESSION
2.394				10.845	1.775	60.24
2.453	-0.0452			15.901	1.705	64.17
2.508	-0.1009	0.0724		14.412	1.659	66.89
2.365	-0.0668	0.1239	-0.0951	15.302	1.629	68.87

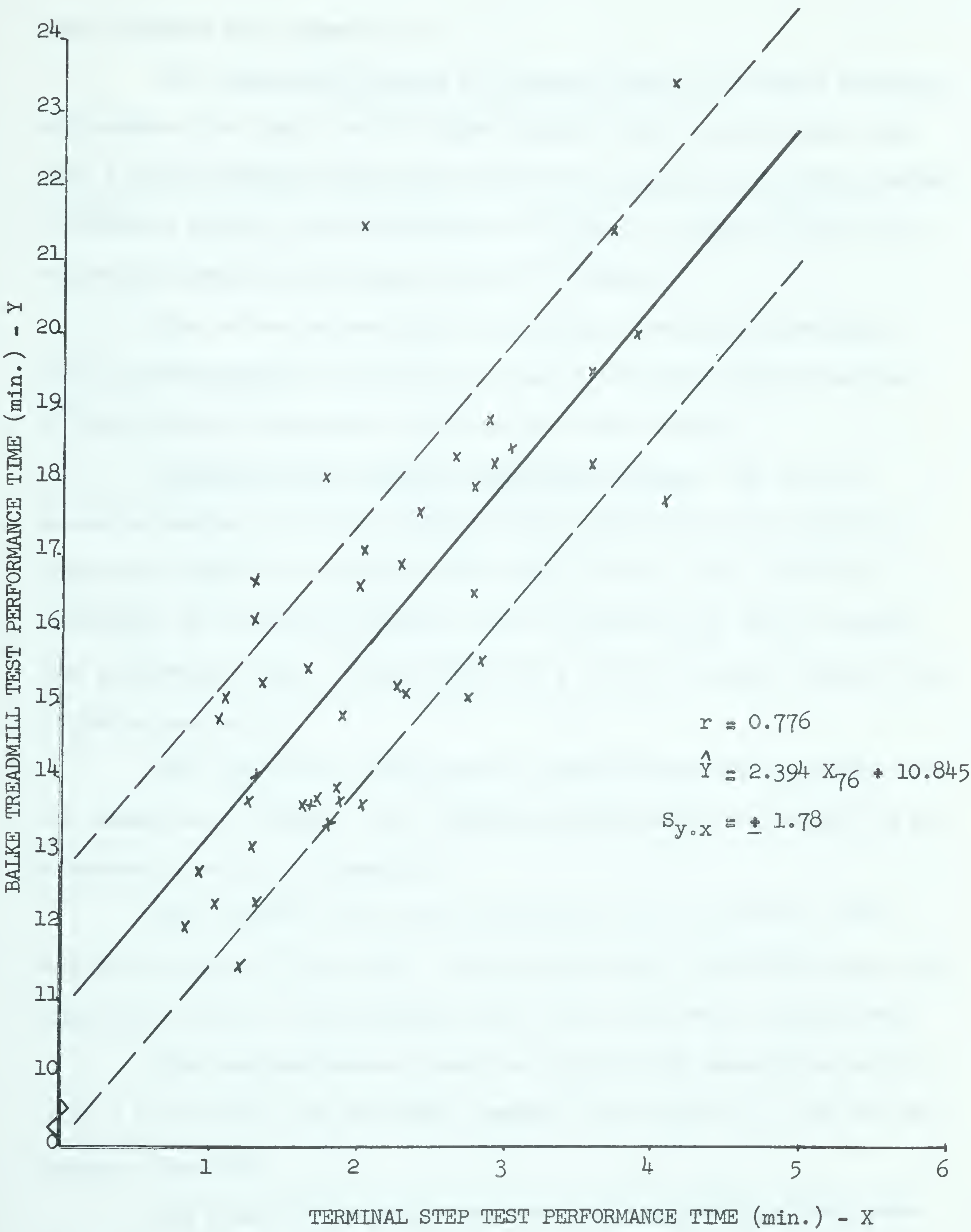

FIGURE V THE RELATIONSHIP BETWEEN TERMINAL STEP TEST AND BALKE TREADMILL TEST.

dent variables (see Appendix C).

The regression line and its standard error of estimate relating performance time (min.) in the Balke Treadmill test to performance time (min.) in the Terminal Step test is plotted in Figure 5. The data plotted in Figure 5 reveals the distribution of subjects in sample one about the regression line and one standard error of estimate.

Due to the introduction of increasing variables (dimensions) with the aforementioned equations B, C and D, graphical interpretations of these multiple regression equations have been omitted.

Validity of the Multiple Regression Analysis. In order to determine whether or not the relationships established in the multiple regression analysis had resulted from chance factors and to study how accurately the developed equations were as predictors of Balke Treadmill test performance time, a second sample (N = 45) was randomly selected from a similar population.

The descriptive statistics for observations taken on sample two are summarized in Table X. The individual measurements for sample two are presented in detail in Appendix D.

The subjects were in the age range of 17 to 21 years, with a mean age of 18.56 ± 0.87 years. The mean total body weight and erect body height were 70.55 ± 6.59 kilograms and 1.78 ± 0.072 metres respectively.

The mean performance times for the two work capacity tests were 16.56 ± 2.43 minutes for the Balke Treadmill test and 2.32 ± 1.04 for the Terminal Step test.

The means for barometric pressure and temperature during phase two testing were 707.17 ± 8.77 millimeters and 20.13 ± 1.06 degrees centigrade respectively.

TABLE X

MEANS, STANDARD DEVIATIONS AND RANGES OF OBSERVATIONS MADE ON SAMPLE TWO ($N = 45$)

VARIABLE	MEAN	STANDARD DEVIATION	RANGE
AGE (yrs.)	18.56	0.87	17 - 21
WEIGHT (kgs.)	70.55	6.59	56.25 - 89.81
HEIGHT (m)	1.78	0.072	1.63 - 1.93
STEP TEST PERFORMANCE TIME (min.)	2.32	1.04	0.44 - 5.14
TREADMILL PERFORMANCE TIME (min.)	16.56	2.43	11.02 - 20.87
BAROMETRIC PRESSURE (mm)	707.17	8.77	688 - 721
TEMPERATURE (°C)	20.13	1.06	19 - 23

In Appendix D, the observed and predicted Balke Treadmill test performance times for sample two are presented in tabular form. The predicted performance times for sample two were calculated by substituting an individual's appropriate Terminal Step test values in the four aforementioned equations.

The standard error of estimate in predicting treadmill test performance time for sample two from the four equations are presented in Table XI. The standard errors of estimate for equations A, B, C and D were $\pm$ 1.149, $\pm$ 1.326, $\pm$ 1.509 and $\pm$ 1.563 minutes, respectively.

A Pearson Product-Moment correlation coefficient was determined between performance time in the Balke test and performance time in the Step test for sample two, yielding an $r = 0.892$ which was statistically significant at the .01 level of confidence. In testing the significance of the difference between the coefficients of correlation of performance time in the two work capacity tests for sample one ($r = 0.776$) and sample two ($r = 0.892$), a z value equal to 1.79 was obtained. This z value, which is a unit-normal-curve deviate, indicated that there was no statistically

TABLE XI

STANDARD ERRORS OF ESTIMATE
FOR SAMPLE TWO (N = 45)

PREDICTION EQUATION	STANDARD ERROR OF ESTIMATE (min.)
A.	1.149
B.	1.326
C.	1.509
D.	1.563

significant difference between the two correlation coefficients.

The regression line, its standard error of estimate and the standard error of estimate for sample two relating performance time (min.) in the Balke Treadmill test to performance time (min.) in the Terminal Step test are plotted in Figure VI. The data plotted in Figure VI reveals the distribution of subjects in sample two about the regression line and one standard error of estimate for samples one and two.

Performance Time Norms. A normative table, in standard score form, for performance time in the Terminal Step and the Balke Treadmill tests, as derived from the data collected on 90 subjects in this investigation, is shown in Table XII.

The mean performance times for the 90 subjects in the Terminal Step test and in the Balke Treadmill test were 2.24 minutes and 16.29 minutes, respectively.

The standard score increment in units of 5 for the Terminal Step test was 0.293 minutes and for the Balke Treadmill test was 0.787 minutes.

The combined range of scores was 0.44 to 5.14 minutes for the Terminal Step test and 11.02 to 23.55 minutes for the Balke Treadmill test.

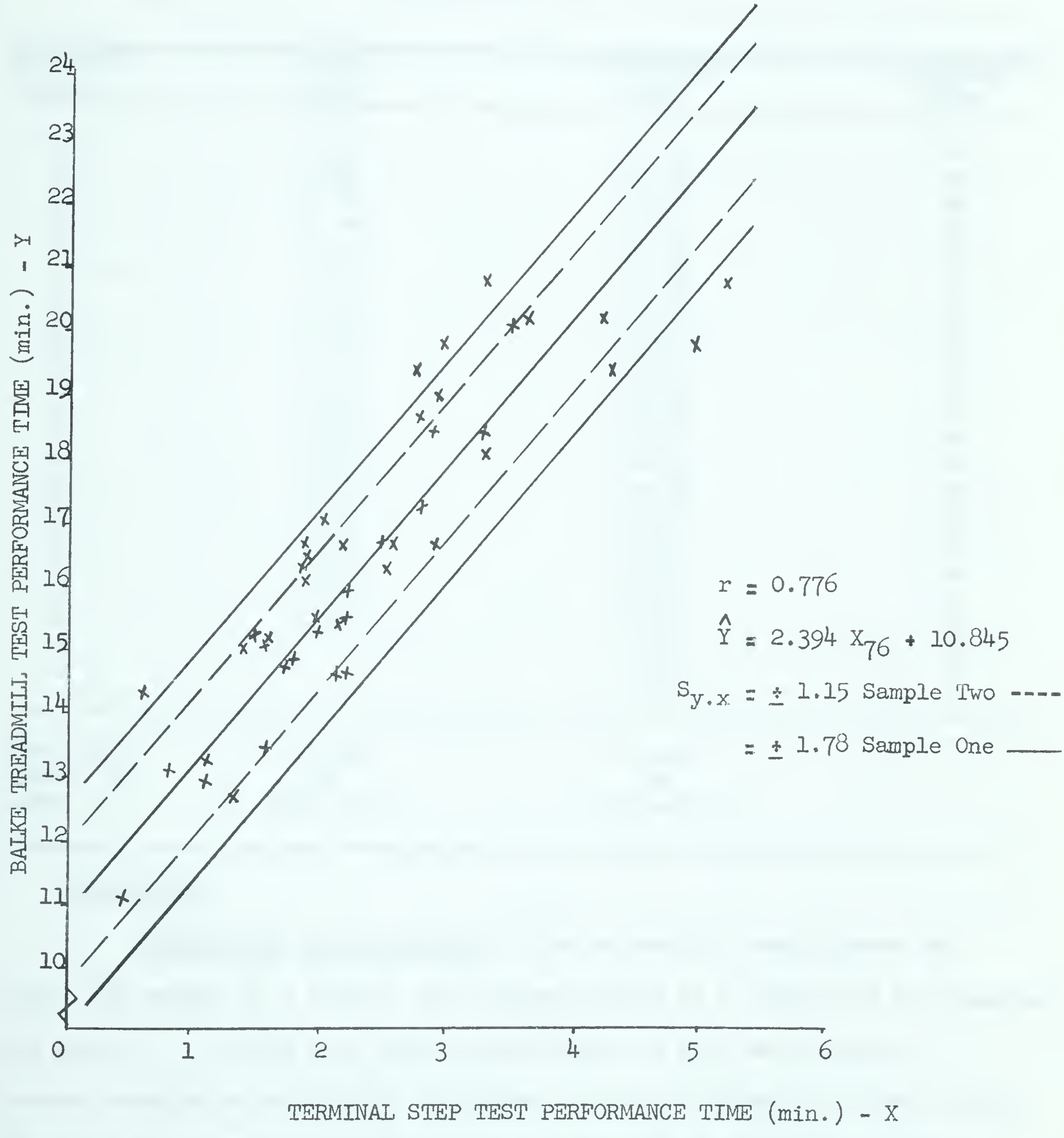

FIGURE VI THE RELATIONSHIP BETWEEN TERMINAL STEP TEST AND BALKE TREADMILL TEST.

TABLE XII

STANDARD SCORE NORMS
FOR
THE TERMINAL STEP AND THE BALKE TREADMILL TESTS
PERFORMANCE TIME (Min.)

STANDARD SCORE	STEP TEST	TREADMILL TEST	STANDARD SCORE
100	5.18	24.17	100
95	4.89	23.38	95
90	4.59	22.60	90
85	4.30	21.81	85
80	4.01	21.02	80
75	3.71	20.23	75
70	3.42	19.44	70
65	3.13	18.66	65
60	2.83	17.87	60
55	2.54	17.08	55
50	2.24	16.29	50
45	1.95	15.51	45
40	1.66	14.72	40
35	1.37	13.93	35
30	1.07	13.14	30
25	0.78	12.36	25
20	0.48	11.57	20
15	0.19	10.78	15
10	0.00	9.99	10
5		9.21	5
0		8.42	0
SIGMA (S)	0.978	2.625	
NUMBER (N)	90	90	
RANGE	0.44-5.14	11.02-23.55	

Discussion.

Reliability of Measurements. The reliability coefficients for total body weight ($r = 0.998$), for vertical height ($r = 0.999$) and for standing leg length ($r = 0.998$) were highly significant and were well above the minimum acceptable reliability coefficient of 0.90 as stated in Clarke (5:35). The value for total body weight was very comparable to the value reported by Dempsey (6:94) ($r = 0.99$) and Coyne (7:45) ($r = 0.985$).

The two major reasons which may have accounted for the failure to

obtain perfect reliability coefficients for the above measures were: a) the fluctuation in time of measurement from day to day, and b) errors of measurement.

The calculated test-retest reliability coefficients of trial means for the three strength measures - plantar flexion ($r = 0.848$), knee extension ($r = 0.867$) and hip extension ($r = 0.843$) were low in comparison to those attained by Clarke (8), who reported objectivity coefficients of 0.93, 0.94 and 0.94 for these three measures respectively. In view of the fact that standardized testing procedures were followed as nearly as possible, the uncontrolled learning and motivational factors would appear to be plausible explanations for the low strength reliability coefficients.

In contrast to the reliability coefficient for knee extensor strength ($r = 0.867$) determined in this investigation, Kerr (9:66), Richardson (10:43) and Williamson (11:25) reported reliability coefficients of 0.84, 0.91 and 0.86 respectively for the same measure.

The reliability coefficient of 0.988 calculated for Terminal Step test performance time represented a mean difference between tests of 0.04 minutes. The reproduceability of bench stepping times in the present study, under conditions whereby the test is terminated at a heart rate of 180 beats per minute, was apparently higher than that found in other investigations where a terminal heart rate was not employed. Reliability coefficients ranging from 0.73 to 0.94 (12) were reported with a physical efficiency index utilized as the obtained score and not performance time. Therefore, because of differences in experimental methods, a true comparison was not possible.

The reproduceability of performance times in the Balke Treadmill test resulted in a reliability coefficient of 0.975 which represented a mean difference between trials of 0.11 minutes. This value was highly significant and comparable to values reported by other authors (6, 13, 14, 15).

Dempsey (6:95) obtained a reliability coefficient of 0.964 with 20 subjects for treadmill performance time. Cooper (13:68) and Hodgson (14:47) reported values of 0.880 and 0.842 with 30 and 33 subjects respectively.

Extracting test-retest treadmill performance time data on eleven subjects from Balke's (15:10) investigation, a Spearman's Coefficient of Rank Correlation (16:179) was computed and resulted in a rho equal to 0.914 - statistically significant at the .01 level of confidence.

Although comparable methods were employed in this and the aforementioned investigations, a higher reliability coefficient of treadmill performance time was obtained in the present study. The fact that performance time was recorded to the nearest tenth of a minute in this study and not to the nearest half or full minute as in the other investigations may explain the higher reliability coefficient.

The reliability coefficients for pre-exercise standing heart rate for the Terminal Step test were significant and comparable to the value procured from data in an investigation by Morehouse (17:43). A Spearman's rho of 0.61 was calculated for the Morehouse data which was statistically significant at the .01 level of confidence for 20 subjects.

Pre-exercise standing heart rate reliability coefficients for the Balke Treadmill test were not as stable as those values reported for the Terminal Step test. In addition, the reliability coefficient for pre-exercise standing heart rate at 1.5 minutes was not significant and indicated agreement with the value ($r = 0.419$) reported by Dempsey (6:95).

It appears that an individual's pre-test apprehension is more apparent before an inexperienced exercise - treadmill walking - than before a more commonly experienced exercise - bench stepping - in spite of a training session.

Although pre-exercise standing heart rate reliability coefficients

in the present study were statistically significant in all but one instance, they were too low to be of any reproduceable consequence. Emotion (18,19), temperature (20) and environmental conditions (21) are factors that have been shown to effect resting heart rates. The probability of these factors influencing the reliability of resting heart rates appears to be quite high and might explain the low but significant values obtained.

Post-exercise standing heart rate reliability coefficients for the Terminal Step and Balke Treadmill tests were fluctuating and statistically significant except in two instances - the values at 2.0 minutes for both tests. These two insignificant values are supported by Dempsey (6:95) who reported values of $r = 0.063$ and 0.345 for post-exercise heart rate in the Balke Treadmill test at 3.0 and 5.0 minutes respectively.

If the behaviour of the heart rate in recovery is largely governed by the intensity and duration of the preceding exercise (17,22,23) and if the test - retest reliability coefficients for the two work capacity tests as employed in this study are very high, it would be logical to expect high reliability coefficients for post-exercise standing heart rates. This logical expectation was not fulfilled. The reliability coefficients for recovery heart rates were too low to be of any consequence. There was a large amount of within individual variation in contrast to the variability between individuals in post-exercise and in pre-exercise standing heart rates.

In view of these findings, there is a definite need for investigations in the area of heart rate reliabilities.

Correlation Analysis. In regard to the relationship of selected anthropometrical and physiological variables to performance time in the Balke Treadmill test (see Table V), the null hypothesis asserted that no relationship existed. Age, weight, height, leg length, leg length - height ratio, bi-lateral strength of the plantar flexors, knee and hip extensors,

pre-exercise standing heart rate at 0.5, 1.0 and 1.5 minutes and post-exercise standing heart rate at every level are variables which fail to reject the null hypothesis. Pre-exercise standing heart rate at 2.0 minutes, exercise heart rate at each level and treadmill external work reject the assertion of the null hypothesis.

Dempsey and Hodgson (24), investigating the relationship between treadmill performance time, body composition and body mass in sedentary young men, found no statistically significant relationship between weight or height and treadmill performance time. These results are in agreement with results presented in the present study, in which weight and height accounted for 5.81 and 2.19 percent of the variance in treadmill performance time, respectively.

However, in another investigation, Dempsey (6:138) found an $r = 0.411$ between total body weight and treadmill performance time which was statistically significant at the .05 level of confidence. In the same study (6:139), correlation coefficients of 0.200 and -0.617 were reported for height and pre-exercise standing heart rate respectively to treadmill performance time. The latter of these coefficients was significant at the .01 level of confidence.

In spite of some slight apparent discrepancies between investigations, total body weight and height appear to account for a very small percentage of the variance in treadmill performance time.

In view of the reliability coefficient for pre-exercise standing heart rate ($r = 0.419$) reported by Dempsey (6:95), his correlation coefficient of -0.617 between pre-exercise heart rate and treadmill performance time appears to be of little consequence in terms of prediction. This statement would also apply to the obtained correlation coefficient of -0.295 between pre-exercise standing heart rate at 2.0 minutes and treadmill perform-

ance time in this investigation.

Cureton (25:345) expressed the opinion that leg length was one of the factors dominating performance in a standard treadmill walk - 3.5 miles per hour on an 8.6% grade. The relationship between leg length and performance time in the Balke Treadmill test, resulting in an $r = 0.198$, does not appear to substantiate Cureton's opinion.

Bi-lateral strength of the plantar flexors, knee and hip extensors, and their combined total strength separately accounted for a very small percentage of the variance in treadmill performance time, ranging from 0.14 to 2.96 percent. The utilization of strength - separately or combined - in the ankles, knees or hips as predictors of treadmill performance time appears to be futile.

The correlation coefficients of post-exercise standing heart rates to treadmill performance time were low with a maximal $r = 0.253$ at 4.0 minutes, accounting for 6.40 percent of the variance. These correlation coefficients were quite comparable to correlation coefficients of -0.167 and -0.369 at 3.0 and 5.0 minutes respectively reported by Dempsey (6:139).

Increasing correlation coefficients resulted between exercise heart rates from 0.5 to 11.5 minutes inclusive and treadmill performance time. An exercise heart rate at 0.5 minutes accounted for 22.09 percent of the variance in treadmill performance time; while an exercise heart rate at 11.5 minutes accounted for 80.46 percent of the variance in treadmill performance time. These findings appear to be quite logical. As the work load and heart rate increase each minute during a test, the correlation coefficient between heart rate at a specific moment and performance time in the test should also increase.

The coefficient of correlation ($r = 0.749$) between treadmill external work and treadmill performance time, although highly significant, appears

to be a spurious correlation of no value. A part-whole correlation (1:164) has arisen where the total score - treadmill external work - is correlated with a subscore - treadmill performance time - which is a part of the total score.

With reference to the relationship of selected anthropometrical and physiological variables to performance time in the Terminal Step test (see Table VI), a true comparison of results with the reviewed investigations is futile with one exception. Past investigators (12,26,27,28,29,30) have correlated the independent variables in question to a Step test Index of Fitness (31) consisting of test duration and recovery pulse counts. In the present study, the independent variables have been correlated with performance time.

Cullumbine (32) reported that weight, height and leg length correlated significantly with the Exhaustion Step test score at the .01 level of confidence. A correlation coefficient of 0.274 was reported between height and Exhaustion Step test score for 1000 Ceylonese males, aged 21 to 25. The coefficients of correlation of weight and leg length to Exhaustion Step test score were not reported.

In reference to Cullumbine's Exhaustion Step test - 20 inch bench, 30 steps per minute till exhaustion, an important psychological variable was uncontrolled. Each subject was allowed to determine his own exhaustion point in the test; hence, the experimenter did not control a subject's exhaustive performance.

Due to the number of subjects employed by Cullumbine, a very low correlation coefficient would be significant. In spite of the significance, an $r = 0.274$ accounts for only 7.51 percent of the variance in Exhaustion Step test score. In the present study, a corresponding r of -0.124 was obtained and accounted for 1.54 percent of the variance in Terminal Step test

performance time. Neither of these two correlation coefficients would be very beneficial in terms of prediction.

The relationship of age, total body weight, vertical height, standing leg length and leg length - height ratio to performance time in the Terminal Step test was not significant. Weight accounted for the largest percent - 5.48 - of the variance in step test performance time; while leg length accounted for the smallest percent -0.15. Hence, these factors have little influence on an individual's Terminal Step test performance time.

The correlation coefficients of the strength measures to Terminal Step test performance time were very low and not significant. Bi-lateral strength of the plantar flexors, knee and hip extensors and their combined total strength individually accounted for a very small percentage of the variance in step test performance time, ranging from 0.69 to 6.97 percent. The futility of these strength measures being employed as predictors of Terminal Step test performance time is extremely evident.

The correlation coefficients of pre-exercise standing heart rate to step test performance time were low but significant in three of the four levels -0.5, 1.0 and 2.0 minutes. The maximal $r = -0.402$ accounted for 16.16 percent of the variance in step test performance time. Resultingly, pre-exercise standing heart rates appear to be independent of Terminal Step test performance time and to have little influence on this performance time.

The relationship between post-exercise standing heart rate and performance time in the Terminal Step test did not result in significant correlation coefficients at any level. The percentage of the variance of step test performance time accounted for by post-exercise heart rates ranged from 0.00 percent at 3.5 minutes to 1.32 percent at 1.5 minutes. Post-exercise standing heart rates also appear to be independent of Step test performance time and to have negligible influence on this performance time.

Exercise heart rates correlated highly with step test performance time as would be expected. An exercise heart rate at 0.5 minutes accounted for 50.27 percent of the variance in step test performance time and increased to 72.25 percent at 1.0 minutes. Exercise heart rates and step test performance time are not to be considered independent of each other; exercise heart rates under a constant work load appear to have a strong influence on an individual's performance time in the Terminal Step test.

Negative correlation coefficients were obtained between exercise heart rates and performance times in the two work capacity tests. The explanation for this phenomena is that exercise heart rates at specific times were correlated with test performance times - the lower the exercise heart rate at a specific time, the longer the duration of test performance; and conversely, the higher the exercise heart rate at the same specific time, the shorter the duration of test performance.

A part-whole spurious correlation coefficient has resulted between step test performance time and step test external work. This spurious correlation coefficient appears to be of little practical value.

In spite of the fact that previous investigators correlated certain independent variables to a Step test Index of Fitness, the results of this investigation tend to affirm the findings of those studies which reported insignificant correlations with the Step test Index of Fitness. Seltzer (26) reported that there was no relationship between stature, weight, lower extremity length or lower leg length and the Step test Index of Fitness. Bookwalter (27) found no relationship between age ($r = -0.056$), height ($r = -0.092$) or weight ($r = 0.086$) and the Step test Index. Montoye (12) found no significant relationship between the Fitness Index of the Step test and age, weight or height. Keen and Sloan (29) found no significant correlation between weight, height or leg length, and test index scores. Eurard (30)

reported that there was no statistically significant correlation between step test index and leg length.

There appears to be a general futility in trying to obtain profitable relationships between specific isolated factors and general physical working capacity - exemplified in the Balke Treadmill and Terminal Step tests. A dissection of the organism into several components for analysis does not seem to warrant significant relationships with performance in treadmill walking and bench stepping. A single measurement of the organism during performance which is dependent upon the totality of the organism - heart rate - appears to warrant fertile relationships with general physical working capacity which is also dependent upon the organism as a whole.

With respect to the relationship of specific Terminal Step test parameters to performance time in the Balke Treadmill test (see Table VII), there was no experimental evidence in the studies reviewed examining these specific relationships.

Terminal Step test post-exercise standing heart rates from 0.5 to 7.0 minutes were not significantly correlated with treadmill performance time. The variance in treadmill performance time accounted for by the variance in step test post-exercise heart rates ranged from 0.18 percent at 2.0 minutes to 7.02 percent at 0.5 minutes. These fluctuating associations are of little consequence in terms of prediction.

Step test exercise heart rate at 0.5 and 1.0 minutes yielded correlation coefficients of -0.512 and -0.643, respectively, with treadmill performance time. These variables respectively accounted for 26.21 and 41.34 percent of the variance in treadmill performance time. Step test external work correlated highly with treadmill performance time, yielding a coefficient of 0.711. Hence, 50.55 percent of the variance in Treadmill performance time can be attributed to the variance in step test external work.

A plausible explanation for the statistically significant relationships between step test exercise heart rates or external work and treadmill performance time is the fact that these particular variables also correlate significantly with step test performance time (see Table VI). In turn, step test performance time was significantly correlated with treadmill performance time. In other words, heterogeneity with respect to step test performance time tended to produce significant correlations between step test exercise heart rates and treadmill performance time and also between step test external work and treadmill performance time (1:164).

Performance time in the Terminal Step test was significantly correlated to performance time in the Balke treadmill test, yielding a coefficient of 0.776. The percentage of the variance in treadmill performance time which can be attributed to the variance of step test performance time was 60.22 percent. This result indicated that there was 60.22 percent performance generality between the Balke Treadmill test and Terminal Step test; and that there was 39.78 percent performance specificity in these two work capacity tests.

Montoye (12) reported correlation coefficients of -0.232, 0.286 and 0.091 between Harvard Step test scores and half-mile run, maximal sit-ups and bicycle ergometer test respectively. These results corroborated the work of Cureton and Karpovich; indicating that there apparently is some slight relationship between step test scores and work capacity but it is of little practical importance. Montoye's results appear to infer that there was some slight relationship between the employed tasks but performance in the tests was task specific.

Subjective observation of the Balke Treadmill and Terminal Step tests revealed several comparable aspects. These were:

1. Similar muscle groups are utilized for performance but not

to the same extent,

2. Performance time is based on a terminal heart rate of 180 beats per minute and

3. A large amount of external work is performed in each test.

One evident difference between the tests was the work load. In the treadmill test, the work load is gradually increased; while in the step test, the work load is constant. On this basis, the Terminal Step test would appear to be more of a maximal that sub-maximal work capacity test.

In the statement of the problem, the Terminal Step test was assumed to be a measure of man's capacity to perform physical work. Granted that the Balke Treadmill test measures physical work capacity, a correlation coefficient of 0.776 between the tests would confirm the assumption to a certain degree. The two tests apparently measure the same entity but the nature of the tests varies the degree of measurement.

On the strength of the results of the present study, the following hypothesis appears to be warranted for investigation. There should be a significant relationship between performance time in the Balke Treadmill test and performance time in a multi-level step test in which the work load is gradually increased and the test is terminated at a heart rate of 180 beats by minute. The multi-level step test, developed by Balke, is reported in an article by Faulkner and Montoye (33).

Multiple Regression Analysis. In the area of multiple regression analysis of step test parameters, as utilized in the present study, to performance time in the Balke treadmill test, there were no closely allied investigations in the studies reviewed.

The single specific Terminal Step test parameter which contributed the most to the variance of Balke Treadmill test performance time was step test performance time. This variable accounted for 60.24 percent of the

total interpersonal variance in treadmill performance time and yielded a beta coefficient with a t value of 8.07 which was statistically significant at the .001 level of confidence for 43 degrees of freedom.

The inclusion of step test post-exercise heart rates at 2.5, 5.5 and 7.0 minutes into the regression analysis accounted for an additional 3.93, 2.72 and 1.98 percent, respectively, of the total variance. The beta coefficient for post-exercise heart rate at 2.5 minutes, upon initial entry into the regression analysis, resulted in a t value of -2.14 which was statistically significant at the .05 level of confidence. However, the beta coefficients procured for the two other post-exercise heart rates were not statistically significant upon their initial introduction into the multiple regression analysis.

The total variance accounted for by all four variables was 68.87 percent and the variance accounted for by step test performance time and post-exercise heart rate at 2.5 minutes was 64.17 percent. These two variables provided the statistically significant contributions in treadmill performance time. Introduction of the two other post-exercise heart rate variables created regression equations which can not be considered useful because their beta coefficients were not statistically significant.

Although statistically significant, step test post-exercise heart rate at 2.5 minutes accounted for only 3.93 percent of the variance in treadmill performance time. This percentage was very low in comparison to that of step test performance time, 60.24 percent. In addition, an individual's post-exercise heart rate at 2.5 minutes was rather unreliable $-r_{xx} = 0.646$. As well, this variable only yielded a correlation coefficient of -0.123 with treadmill performance time, and its beta coefficient was just above borderline significance at the .05 level. Therefore, the use of this variable in aiding the prediction of treadmill performance time

appears to be extremely questionable.

Step test performance time was the best single variable in the prediction of treadmill performance time, as might be expected from the discussion of the correlation analysis section. The factors of the body utilized in Terminal Step test performance are apparently employed to an appreciable extent in performance on the Balke Treadmill test. In spite of this fact, 39.76 percent of the variance in treadmill performance time was not accounted for. Hence, in terms of practical prediction, step test performance time as a predictor of performance time in the Balke Treadmill test appears to be quite limited.

Validity of the Multiple Regression Analysis. A subjective comparison of sample one and sample two in terms of age, weight, height, step test and treadmill test performance times seems to indicate that the two randomly selected samples were from a similar population. The mean age in years for sample one was 18.71 and for sample two was 18.56. The means for weight and height for samples one and two were 69.02, 1.75 and 70.55, 1.78 kilograms and metres respectively. The step test performance time mean for sample one was 2.17 minutes, and for sample two was 2.32 minutes. The means for treadmill performance time for samples one and two were 16.03 and 16.56 minutes respectively. In view of the fact that there was no statistically significant difference between the correlation coefficients of performance time in the step test to performance time in the treadmill test for sample one and two, it must be assumed that samples one and two were selected from the same population which would substantiate the initial subjective comparison.

With the two samples from the same population, the prediction equations for treadmill performance time - derived from sample one data - should procure favourable results for sample two. A standard error of

estimate equal to 1.149 minutes was obtained for sample two, utilizing the equation:-

$$\text{Treadmill performance time (min.)} = 2.394 \times \text{Step test performance time (min.)} + 10.845,$$

which was a smaller standard error of estimate than that for sample one - 1.775 minutes. This decrease in the standard error of estimate for sample two was probably due to sampling error within the limitations of the present study. The deviations of the individual scores about the regression line (see Figures V and VI) were smaller in magnitude for sample two than for sample one. However, this decreased standard error of estimate appears to indicate that the aforementioned equation predicted individual treadmill test performance times fairly accurately for sample two.

Inspection of Figures V and VI revealed a common general tendency - increased duration in an individual's Terminal Step test performance time resulted in larger deviations between observed and predicted treadmill test performance times. This observational fact would seem to indicate that the prediction of treadmill test performance time from Terminal Step test performance time was relatively successful for the particular samples employed when the step test scores ranged from approximately 0.30 to 3.50 minutes. However, as the step test scores increased, the accuracy in prediction of an individual's treadmill performance time decreased. The difference in the nature of these two work capacity tests, appears to limit the prediction of performance time in the Balke Treadmill test from Terminal Step test performance time.

Due to the fact that the prediction equations B, C and D were not considered to be of any consequence, their respective validity aspects in terms of standard errors of estimate for sample two have not been discussed.

Performance Time Norms. The normative chart (see Table XII), in standard score form, for performance time in the Terminal Step and the Balke Treadmill tests was comparable to a normative chart reported by Howell, et al (34) in regard to treadmill performance times. They found a mean treadmill test performance time of 15.49 ± 2.99 minutes for college males with a mean age of 19.23 years and a mean weight of 73.06 kilograms. In contrast, the mean treadmill test performance time obtained in the present study was 16.29 ± 2.625 minutes for college freshmen with a mean age of 18.63 years and a mean weight of 69.78 kilograms.

The small differences in the aforementioned specific values of the two studies may be accounted for by the size and nature of the samples employed. Howell, et al (34) utilized some of their own collected data and that of other investigators with the result that the nature of the subjects ranged from obese sedentary males to well - trained college athletes with a sample size of 135. Whereas, 90 college freshmen were employed as subjects in the present study.

The reviewed studies revealed no closely allied investigations in the area of performance time norms for a Terminal Step test as employed in this investigation. Hence, a discussion of possible generalizations or comparisons has been omitted.

In reference to the normative chart, its application must be limited to the particular population from which the derivative data of the two samples was extracted.

REFERENCES

1. McNemar, C., Psychological Statistics, New York: John Wiley and Sons, Inc., 1962.

2. Smilie, K. M., (Programmer), Simple Correlations, Programme No. 1620-013, University of Alberta Computing Centre, 1963.

3. Efroymson, M. A., "Multiple Regression Analysis", Mathematical Methods for Digital Computers, New York: John Wiley and Sons, Inc., 1960, pp. 191-203.

4. Smilie, K. M., (Programmer), Stepwise Regression - Revision 2, Programme No. 1620-019, University of Alberta Computing Centre, 1963.

5. Clarke, H. H., Application of Measurement to Health and Physical Education, 3rd ed., Englewood Cliffs: Prentice-Hall, Inc., 1959.

6. Dempsey, J. A., "Anthropometrical and Physiological Observations of Obese and Non-Obese Young Men Undergoing a Program of Vigorous Physical Exercise", Unpublished Master's Thesis, University of Alberta, 1963.

7. Coyne, L. L., "The Relationship of Maximal Oxygen Intake to Body Composition and Total Body Weight in Active Males", Unpublished Master's Thesis, University of Alberta, 1963.

8. Clarke, H. H., A Manual: Cable-Tension Strength Tests, Chicopee: Brown-Murphy Co., 1953.

9. Kerr, B. A., "The Effect of Strength Training Upon Speed of Movement and Reaction Time in a Knee Extension Movement," Unpublished Master's Thesis, University of Alberta, 1964.

10. Richardson, J. R., "The Effect of Brief Isometric and Isotonic Exercise Programmes on the Development of Strength and Muscular Endurance," Unpublished Master's Thesis, University of Alberta, 1963.

11. Williamson, K. R., "Quantitative Strength Changes Resulting from Varied Isometric Contraction," Unpublished Master's Thesis, University of Alberta, 1964.

12. Montoye, H. J., "The Harvard Step Test and Work Capacity," Revue Canadienne de Biologie, vol. 11 (Mar. 1953), pp. 491-99.

13. Cooper, L. A., "A Comparison of the Effects of Short Intensive and Prolonged Intensive Exercise Programs on Treadmill Performance and Certain Cardio - Respiratory Functions," Unpublished Master's Thesis, University of Alberta, 1963.

14. Hodgson, J. L., "The Effect of Circuit Training and Isometric Exercise on Treadmill Performance," Unpublished Master's Thesis, University of Alberta, 1963.

15. Balke, B., "Correlation of Static and Physical Endurance," Report No. 1, Randolph Field, Texas: School of Aviation Medicine, April 1952, Project Number 21-32-004. Article to the Writer, May 1963.

16. Ferguson, G. A., Statistical Analysis in Psychology and Education, Toronto: McGraw-Hill Book Company, Inc., 1959.

17. Morehouse, L., "A Study of the Response of the Heart to Various Types of Exercise," Doctoral Thesis, University of Iowa, 1941, Microcard.

18. Brouha, L., Health, C. W., "Resting Pulse and Blood Pressure Values in Relation to Physical Fitness in Young Men," The New England Journal of Medicine, vol. 228 (April 1943), pp. 473-7.

19. Kozar, A. J., "A Study of Telemetered Heart-Rate During Sports Participation of Young Adult Men," Doctoral Thesis, University of Michigan, 1961, Microcard.

20. LeBlanc, J. A., "Use of Heart Rate as an Index of Work Output," Journal of Applied Physiology, vol. 10 (Mar. 1957), pp. 275-80.

21. Taylor, H. L., Yangwang, R. L., And Blomquist, G., "The Standardization and Interpulation of Submaximal and Maximal Test of Working Capacity," Pediatrix, vol. 32 (1963), pp. 703-22.

22. Rodahl, K., Horvath, S. M., "Cardiac Performance," Muscle as a Tissue, New York: McGraw-Hill Book Company, Inc., 1962, pp. 243-58.

23. Müller, E. A., "The Physiological Basis of Rest Pauses in Heavy Work", The Journal of Experimental Physiology, vol. 38 (1953), pp. 205-15.

24. Dempsey, J. A., Hodgson, J. L., "The Relationship Between Treadmill Performance, Body Composition and Body Mass In Obese, and Non-Obese, Sedentary and Active Young Men," A paper given to the Research Section of C.A.H.P.E.R., Saskatoon, June 1963.

25. Cureton, T. K., Physical Fitness of Champion Athletes, Urbana: University of Illinosi, 1951.

26. Seltzer, C. C., "Anthropometric Characteristics and Physical Fitness," Research Quarterly, vol. 17 (Mar. 1946), pp. 10-20.

27. Bookwalter, K. W., "A Study of the Brouha Step Test," The Physical Educator, vol. 5 (May 1948), p. 3.

28. Elbel, E. R., Reid, M., Ormond, D. E., "Comparison of Certain Tests of Physical Fitness and Certain Bodily Measurements," Journal of Applied Physiology, vol. 12 (Jan. 1958), pp. 37-41.

29. Keen, E. N., Sloan, A. W., "Observations on the Harvard Step Test," Journal of Applied Physiology, vol. 13 (Sept. 1958), pp. 241-3.

30. Eurard, E., "Use and Value of the Step Test in Military Pilot Selection," United States Armed Forces Medical Journal, vol. 10 (June 1959), pp. 659-74.

31. Johnson, R. E., Brouha, L., Darling, R. C., "A Test of Physical Fitness for Strenuous Exertion," Revue Canadienne de Biologie, vol. 1 (June 1942), pp. 491-503.

32. Cullumbine, H., "Relationship Between Body Build and Capacity for Exercise," Journal of Applied Physiology, vol. 2 (Sept. 1949), pp. 155-68.

33. Faulkner, J. A., Montoye, H. J., "The Body Build, Strength, Physical Activity, and Work Capacity of Business Executives," A paper presented at A. A. H. P. E. R. National Convention, May 1963.

34. Howell, M. L., Kerr, B. A., Bakogeorge, A. P., "Progressive Treadmill Test Norms for College Males," Accepted for publication, Research Quarterly, Jan. 1964.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was twofold:

a) to investigate the relationship of selected anthropometrical and physiological variables to performance in the Balke Treadmill test and a Terminal Step test, and

b) to determine the relationship of specific parameters of the Terminal Step test to performance time in the Balke Treadmill test.

The subsidiary problems were to determine the validity of the multiple regression equation established for performance time in the Balke Treadmill test and to construct a normative table in standard score form for performance times in the Balke Treadmill and Terminal Step tests.

Forty-five of an initial fifty-five randomly selected University of Alberta freshmen, ranging in age from 17 to 27 years, participated in the twofold problem of the study. Age, weight, height, leg length and leg length - height ratio measurements were obtained for all subjects. As well, they were tested for: a) bi-lateral strength of the plantar flexors, knee extensors and hip extensors, b) performance time in the Balke Treadmill test and performance time in a Terminal Step test. Treadmill and step test external work were calculated for each subject. Reliability measurements were carried out for weight, height, leg length, all strength measures, pre - and post-exercise heart rates, Balke Treadmill test performance time and Terminal Step test performance time (N = 30). Pre -, post - and exercise heart rates were recorded for the treadmill and step tests. All determinations were completed on individual subjects within a five week period.

The main problem data was analyzed by "Simple Correlations" (1)

which provided means, variances, standard deviations and an intercorrelation of all measures. The relationship of specific Terminal Step test parameters to Balke Treadmill test performance time was procured through a "Stepwise Regression - Revision 2" (2) which included an intercorrelation of these measures, a single regression equation and multiple regression equations. Corresponding beta coefficients, t and F ratios, standard errors and the percentage of the variance accounted for were also obtained.

For the subsidiary problems, another forty-five subjects were randomly selected from the required freshmen physical education classes at the University of Alberta. Age, weight, and height measurements were obtained. All subjects were tested for performance time in the Terminal Step test. Predicted Balke Treadmill test performance times were then calculated for each subject, utilizing four selected regression equations; and the actual treadmill performance time for each subject was obtained. Standard errors of estimate between predicted and observed treadmill performance times were calculated. As well, the relationship between step test performance time and treadmill performance time was procured.

Combining performance time data for samples one and two, a normative chart in standard score form was established for performance time in the Balke Treadmill and Terminal Step tests.

On the basis of the statistical analysis and within the limitations of this study, the following conclusions appear to be warranted:

1. The reliability coefficients obtained for pre - and post-exercise heart rates were too low to be of any reproduceable consequence.

2. There was no statistically significant relationship between age, weight, height, leg length, leg length - height ratio, bilateral strength of the plantar flexors, knee and hip extensors, total

combined strength, pre-exercise heart rate at 0.5, 1.0 and 1.5 minutes or post-exercise heart rates and performance time in the Balke Treadmill test.

3. There was a significant but low relationship between pre-exercise heart rate at 2.0 minutes and Balke Treadmill test performance time.

4. Exercise heart rates in the Treadmill test were significantly correlated with performance time in the Balke Treadmill test. The magnitude of the correlation coefficients increased as the time, at which the exercise heart rate was taken, increased.

5. There was a statistically significant relationship, but spurious correlation, between treadmill external work and Balke treadmill test performance time.

6. There was no statistically significant relationship between age, weight, height, leg length, leg length - height ratio, bilateral strength of the plantar flexors, knee and hip extensors, total combined strength, pre-exercise heart rate at 1.5 minutes or post-exercise heart rates and performance time in the Terminal Step test.

7. There were significant but low relationships between pre-exercise heart rate at 0.5, 1.0 and 2.0 minutes and Terminal Step test performance time.

8. Exercise heart rates in the step test were significantly correlated with performance time in the Terminal Step test. The magnitude of the correlation coefficients increased as the time, at which the exercise heart rate was taken, increased.

9. There was a statistically significant relationship, but spurious correlation, between step test external work and Terminal Step test performance time.

10. Terminal Step test post-exercise heart rates were not significantly correlated with Balke Treadmill test performance time.

11. Terminal Step test exercise heart rates and external work were significantly correlated with performance time in the Balke Treadmill test. These significant relationships were unwittingly produced correlations, since Terminal Step test exercise heart rates and external work were highly correlated with Terminal Step test performance time.

12. There was a statistically significant relationship between Terminal Step test performance time and Balke Treadmill test performance time which indicated that factors utilized for performance in the step test were to some extent utilized in the treadmill test. A highly significant relationship between performance time in the two work capacity tests for sample two supported this indication.

13. The single specific Terminal Step test parameter which accounted for the largest percentage of the total interpersonal variance in Balke Treadmill test performance time was step test performance time. The inclusion of Terminal Step test post-exercise heart rates at 2.5, 5.5 and 7.0 minutes theoretically improved the predictability of Balke Treadmill test performance time but were not considered to be of importance in terms of practical prediction.

14. The regression equation, based on Terminal Step test performance time, predicted Balke Treadmill test performance time for the validation sample well within two standard errors of estimate. However, due to the large percentage of total interpersonal variance in treadmill performance time not accounted for, the prediction of Balke Treadmill test performance time by Terminal Step test performance time was considered to be very limited.

15. The normative table for performance time in Balke Treadmill and Terminal Step tests must only be considered applicable to the specific population from which the derivative data was procured.

REFERENCES

1. Smilie, K. M., (Programmer), Simpe Correlations, Programme No. 1620-013, University of Alberta Computing Centre, 1963.

2. Smilie, K. M., (Programmer), Stepwise Regression - Revision 2, Programme No. 1620-019, University of Alberta Computing Centre, 1963.

BIBLIOGRAPHY

Alexander, J. F., Fraser, R. S., Cavero, C., "An Evaluation of the 5BX Program of Exercise by a Treadmill Performance Test," Journal of the Canadian Association for Health, Physical Education and Recreation, vol. 28 (Feb. - Mar. 1962), p. 21.

Alexander, J., Howell, M. L., Fraser, R., Sproule, B., "An Evaluation of the 5BX Program of Exercises by Certain Physiologic Responses to a Treadmill Test," Unpublished Paper, University of Alberta, 1962.

Alexander, J., Howell, M. L., Fraser, R., Sproule, B., "Contributions of Various Sports to Physical Fitness as Assessed by Physiological Responses to a Treadmill Performance Test," Unpublished Paper, University of Alberta, 1963.

Army Air Forces, "Army Air Forces Physical Fitness Testing Program," Research Quarterly, vol. 15 (Mar. 1944), pp. 12-15.

Asmussen, E., Nielsen, M., "Cardiac Output During Muscular Work and Its Regulation," Physiological Review, vol. 35 (1955), pp. 778-800.

Astrand, P.-O., Ryhming, J., "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) From Pulse Rate during Submaximal Work," Journal of Applied Physiology, vol. 7 (Sept. 1954), pp. 218-21.

Astrand, P.-O., "Human Physical Fitness with Special Reference to Sex and Age," Physiological Reviews, vol. 36 (July 1956), pp. 307-35.

Balke, B., "Correlation of Static and Physical Endurance," Report No. 1, Randolph Field, Texas: School of Aviation Medicine, April 1952, Project Number 21-32-004. Article to the Writer, May 1963.

Balke, B., "Gas Exchange and Cardiovascular Functions at Rest and in Exercise under the Effects of Extrinsic and Intrinsic Fatique Factors," Report No. 1, Randolph Field, Texas: School of Aviation Medicine, Feb. 1953, Project Number 21-1201-0014. Article to the Writer, May 1963.

Balke, B., "The Effect of Physical Exercise on the Metabolic Potential, a Crucial Measure of Physical Fitness," Exercise and Fitness, Athletic Institute, 1960, pp. 73-81.

Balke, B., Clark, R. T., "Cardio-Pulmonary and Metabolic Effects of Physical Training," Health and Fitness in the Modern World, Athletic Institute, 1961, pp. 82-9.

Balke, B., Grillo, G. P., Konecci, E. B., Luft, U. C., "Work Capacity after Blood Donation," Journal of Applied Physiology, vol. 7 (Nov. 1954), pp. 231-8.

Balke, B., Ware, R. W., "An Experimental Study of Physical Fitness of Air Force Personnel," United States Armed Forces Medical Journal, vol. 10 (Jan. 1959), pp. 675-88.

Billings Jr., C. E., Tomashefski, J. F., Carter, E. T., Ashe, W. R., "Measurement of Human Capacity for Aerobic Muscular Work," Journal of Applied Physiology, vol. 15 (Nov. 1960), pp. 1001-1006.

Bobbert, A. C., "Physiological Comparison of Three Types of Ergometry," Journal of Applied Physiology, vol. 15 (Nov. 1960), pp. 1007-14.

Bookwalter, K. W., "A Study of the Brouha Step Test," The Physical Educator, vol. 5 (May 1948), p. 3.

Brassfield, C. R., "Some Physiological Aspects of Physical Fitness," Research Quarterly, vol. 14 (Mar. 1943), pp. 106-11.

Brouha, L., "The Step Test: A Simple Method of Measuring Physical Fitness for Muscular Work in Young Men," Research Quarterly, vol. 14 (Mar. 1943), pp. 31-6.

Brouha, L., "Effects of Muscular Work and Heat on the Cardiovascular System," Industrial Medicine and Surgery, vol. 29 (Mar. 1960), pp. 114-20.

Brouha, L., Fradd, N. W., Savage, B. M., "Studies in Physical Efficiency of College Students," Research Quarterly, vol. 15 (Oct. 1944), pp. 211-24.

Brouha, L., Gallagher, J. R., "A Functional Fitness Test for High School Girls," The Journal of Health and Physical Education, vol. 14 (Dec. 1943), p. 517.

Brouha, L., Heath, C. W., Graybiel, A., "The Step Test: A Simple Method of Measuring Physical Fitness for Hard Muscular Work in Adult Men," Revue Canadienne de Biologie, vol. 2 (Feb. 1943), pp. 86-91.

Brouha, L., Heath, C. W., "Resting-Pulse and Blood Pressure Values in Relation to Physical Fitness in Young Men," The New England Journal of Medicine, vol. 228 (April 1943), pp. 473-7.

Brouha, L., Johnson, R. E., "Pulse Rate, Blood Lactate and Duration of Effort in Relation to Ability to Perform Strenuous Exercise," Revue Canadienne de Biologie, vol. 1 (Feb. 1942), pp. 171-8.

Brouha, L., Savage, B. M., "Variability of Physiological Measurements in Normal Young Men at Rest and During Muscular Work," Revue Canadianne de Biologie, vol. 4 (Feb. 1945), pp. 131-43.

Burt, J. J., Blyth, C. S., Rierson, H., "Body Fat, Blood Coagulation Time, and the Harvard Step Test Recovery Index," Research Quarterly, vol. 33 (Oct. 1962), pp. 339-42.

Clarke, H. H., A Manual: Cable-Tension Strength Tests, Chicopee: Brown-Murphy Co., 1953.

Clarke, H. H., Application of Measurement to Health and Physical Education, 3rd ed., Englewood Cliffs: Prentice-Hall, Inc., 1959.

Clarke, H. H., Clarke, D., Developmental and Adapted Physical Education, Englewood Cliffs: Prentice-Hall, Inc., 1963, pp. 73-96.

Clarke, H. L., "A Functional Physical Fitness Test for College Women," The Journal of Health and Physical Education, vol. 14 (Sept. 1943), p. 358.

Cogswell, R. C., Henderson, C. R., Berryman, G. H., "Some Observations on the Effects of Training on Pulse Rate, Blood Pressure and Endurance in Humans, Using the Step Test, Treadmill and Electrodynamic Brake Bicycle Ergometer," American Journal of Physiology, vol. 146 (June 1946), pp. 422-30.

Cook, E. B., Wherry, R. J., "A Statistical Evaluation of Physical Fitness Tests," Research Quarterly, vol. 21 (May 1950), pp. 94-111.

Cooper, L. A., "A Comparison of the Effects of Short Intensive and Prolonged Intensive Exercise Programs on Certain Cardio-Respiratory Functions," Unpublished Master's Thesis, University of Alberta, 1963.

Coyne, L. L., "The Relationship of Maximal Oxygen Intake to Body Composition and Total Body Weight in Active Males," Unpublished Master's Thesis, University of Alberta, 1963.

Cullumbine, H., "Relationship Between Body Build and Capacity for Exercise," Journal of Applied Physiology, vol. 2 (Sept. 1949), pp. 155-68.

Cullumbine, H., "Relationship Between Resting Pulse Rate, Blood Pressure and Physical Fitness," Journal of Applied Physiology, vol. 2 (Nov. 1949), pp. 278-82.

Cullumbine, H., Bibile, S. W., Wikramanayake, T. W., Watson, R. S., "Influence of Age, Sex, Physique and Muscular Development on Physical Fitness," Journal of Applied Physiology, vol. 2 (Mar. 1950), pp. 488-511.

Cureton, T. K., Physical Fitness of Champion Athletes, Urbana: University of Illinois Press, 1951, p. 344.

Cureton, T. K., "Scientific Principles of Human Performance (With Suggestions for Its Development)," Health and Fitness in the Modern World, Athletic Institute, 1961, pp. 347-58.

Dempsey, J. A., "Anthropometrical and Physiological Observations of Obese and Non-Obese Young Men Undergoing a Program of Vigorous Physical Exercise," Unpublished Master's Thesis, University of Alberta, 1963.

Dempsey, J. A., Hodgson, J. L., "The Relationship Between Treadmill Performance, Body Composition, and Body Mass in Obese, and Non-Obese, Sedentary and Active Young Men," A Paper given to the Research Section of C.A.H.P.E.R., Saskatoon, June 1963.

Dixon, W. J., Massey, F. M., Introduction to Statistical Analysis, 2nd ed., Toronto: McGraw-Hill Book Company, Inc., 1957, pp. 366-70.

Durnin, J. V. G. A., Namyslowski, L., "Individual Variations in the Energy Expenditure of Standardized Activities," Journal of Physiology, vol. 143 (Oct. 1958), pp. 573-7.

Efroymson, M. A., "Multiple Regression Analysis," Mathematical Methods for Digital Computers, New York: John Wiley and Sons, Inc., 1960, pp. 191-203.

Elbel, E. R., "The Relationship Between Pre-Exercise and Post-Exercise Pulse Rate," Research Quarterly, vol. 19 (Oct. 1948), pp. 222-8.

Elbel, E. R., Holmer, R. M., "The Relationship Between Pre-Exercise Pulse Rate and Recovery Following Exercise," Research Quarterly, vol. 20 (Dec. 1949), pp. 367-77.

Elbel, E. R., Reid, M., Ormond, D. E., "Comparison of Certain Tests of Physical Fitness and Certain Bodily Measurements," Journal of Applied Physiology, vol. 12 (Jan. 1958), pp. 37-41.

Eurard, E., "Use and Value of the Step Test in Military Pilot Selection," United States Armed Forces Medical Journal, vol. 10 (June 1959), pp. 659-74.

Faine, S., Mathews, D. T., "Physical Fitness Tests on New Zealand School Children," Research Quarterly, vol. 22 (Dec. 1951), pp. 399-408.

Faulkner, J. A., Montoye, H. J., "The Body Build Strength, Physical Activity, and Work Capacity of Business Executives," A Paper presented at A.A.H.P.E.R. National Convention, May 1963.

Ferguson, G. A., Statistical Analysis in Psychology and Education, Toronto: McGraw-Hill Book Company, Inc., 1959.

Fletcher, J. G., "Maximal Work Production in Man," Journal of Applied Physiology, vol. 15 (Sept. 1960), pp. 764-8.

Gallagher, J. R., Brouha, L., "A Simple Method of Testing the Physical Fitness of Boys," Research Quarterly, vol. 14 (Mar. 1943), pp. 23-30.

Gallagher, J. R., Brouha, L., "A Method of Testing the Physical Fitness of High School Girls," Revue Canadienne de Biologie, vol. 2 (Oct. 1943), pp. 395-406.

Gallagher, J. R., Brouha, L., "Physical Fitness: Its Evaluation and Significance," Journal of the American Medical Association, vol. 125 (July 1944), pp. 834-88.

Garrett, H. E., Statistics in Psychology and Education, 5th ed., Toronto: Longmans, Green and Co., 1961.

Hall, S. M., "A Comparative Study of the Carlson Fatique Curve Test, the Brouha Step Test, the Wetzel Grid and the Medical Examination," Doctoral Thesis, Ohio State University, 1948, Microcard.

Hardy, H. L., Clarke, H. L., Brouha, L., "Testing Physical Fitness in Young Women," Revue Canadienne de Biologie, vol. 2 (Oct. 1943), pp. 407-15.

Henry, F. M., "Influence of Athletic Training on the Cardiovascular System," Research Quarterly, vol. 25 (May 1954), pp. 28-40.

Henry, F. M., Berg, W. E., "Physiological and Performance Changes in Athletic Conditioning," Journal of Applied Physiology, vol. 3 (Aug. 1950), pp. 103-111.

Hettinger, T., Birkhead, N. C., Howarth, S. M., Issekutz, B., Rodahl, K., "Assessment of Physical Work Capacity," Journal of Applied Physiology, vol. 16 (Jan. 1961), pp. 153-6.

Hodgson, J. L., "The Effect of Circuit Training and Isometric Exercises on Treadmill Performance," Unpublished Master's Thesis, University of Alberta, 1963.

Hodgson, P., Lopez, A. F., Pilliard, M., Newman, A. S., "A Study of Some Relationships Between Performance Tests and Certain Physiological Measures Associated with Maximal and Submaximal Work," Research Quarterly, vol. 17 (Oct. 1946), pp. 208-23.

Howell, M. L., Coupe, K., "Effect of Blood Loss Upon Performance in the Balke-Ware Treadmill Test," Research Quarterly, vol. 35 (May 1964), pp. 156-65.

Howell, M. L., Hodgson, J. L., Sorenson, J. T., "The Effects of Circuit Training on the Modified Harvard Step Test," Research Quarterly, vol. 34 (May 1963), pp. 154-7.

Howell, M. L., Kerr, B. A., Bakogeorge, A. P., "Progressive Treadmill Test Norms for College Males," Accepted for publication, Research Quarterly, Jan. 1964.

Hunsicker, P. A., "A Validation of Cardiovascular Tests by Cardiac Output Measurements," Doctoral Thesis, University of Illinois, 1950, Microcard.

Janda, F., "A Point in the Discussion on the Physical Fitness of Youth," The Journal of Sports, Medicine and Physical Fitness, vol. 2 (June 1962), p. 121.

Johnson, R. E., Brouha, L., Darling, R. C., "A Test of Physical Fitness for Strenuous Exertion," Revue Canadienne de Biologie, vol. 1 (June 1942), pp. 491-503.

Johnson, R. E., Darling, R. C., Forbes, W. H., Brouha, L., Egana, E., Graybiel, A., "The Effect of a Diet Deficient in Part of the Vitamin B Complex on Men Doing Manual Labor," Journal of Nutrition, vol. 24 (1942), pp. 585-96.

Jokl, E., "Recent Advances in Cardiovascular Research," College Physical Education Association, 62nd Annual Proceedings, 1958, pp. 167-8.

Karpovich, P. V., Physiology of Muscular Activity, 5th ed., Philadelphia: W. B. Saunders Co., 1959.

Karpovich, P. V., Starr, M. P., Weiss, R. A., "Physical Fitness Tests for Convalescents," Journal of the American Medical Association, vol. 126 (Dec. 1944), pp. 873-7.

Keen, E. N., Sloan, A. W., "Observations on the Harvard Step Test," Journal of Applied Physiology, vol. 13, (Sept. 1958), pp. 241-3.

Kerr, B. A., "The Effect of Strength Training Upon Speed of Movement and Reaction Time in a Knee Extension Movement," Unpublished Master's Thesis, University of Alberta, 1964.

Kozar, A. J., "A Study of Telemetered Heart-Rate During Sports Participation of Young Adult Men," Doctoral Thesis, University of Michigan, 1961, Microcard.

Kusinitz, J., Keeney, C. E., "Effects of Progressive Weight Training on Health and Physical Fitness of Adolescent Boys," Research Quarterly, vol. 29 (Oct. 1958), pp. 294-301.

LeBlanc, J. A., "Use of Heart Rate as an Index of Work Output," Journal of Applied Physiology, vol. 10 (Mar. 1957), pp. 275-80.

Linroth, K., "Physical Working Capacity in Conscripts During Military Service," Acta Medica Scandinavica Supplementum 324, vol. 157 (July 1957), p. 126.

McNemar, C., Psychological Statistics, New York: John Wiley and Sons, Inc., 1962.

Miller, A. T., Blyth, C. S., "Influence of Body Type and Body Fat Content on the Metabolic Cost of Work," Journal of Applied Physiology, vol. 8 (Sept. 1955), pp. 139-41.

Miller, W. A., Elbel, E. R., "The Effect Upon Pulse Rate of Various Cadences in the Step-Up Test," Research Quarterly, vol. 17 (Dec. 1946), pp. 263-9.

Montoye, H. J., "An Investigation of Breath-Holding as a Measure of Cardiovascular Fitness," Doctoral Thesis, University of Illinois, 1950, Microcard.

Montoye, H. J., "The Harvard Step Test and Work Capacity," Revue Canadienne de Biologie, vol. 11 (Mar. 1953), pp. 491-99.

Montoye, H. J., "Inter-relation of Maximum Pulse Rate During Moderate Exercise, Recovery Pulse Rate, and Post-Exercise Blood Lactate," Research Quarterly, vol. 24 (Dec. 1953), pp. 453-8.

Morehouse, L., "A Study of the Response of the Heart to Various Types of Exercise," Doctoral Thesis, University of Iowa, 1941, Microcard.

Müller, E. A., "The Physiological Basis of Rest Pauses in Heavy Work," The Journal of Experimental Physiology, vol. 38 (1953), pp. 205-15.

Nagle, F. J., Bedecki, T. G., "The Use of the Exercise Heart Rate Response as a Measure of Circulo-Respiratory Capacity," University of Florida, Article to the Writer, February 1963.

Nagle, F. J., Irwin, L. W., "Effects of Two Systems of Weight Training on Circulo-Respiratory Endurance and Related Physiological Factors," Research Quarterly, vol. 31 (Dec. 1960), pp. 607-15.

Pierson, W. R., Rasch, P. J., "Bruce Physical Fitness Index as a Predictor of Performance in Trained Distance Runners," Research Quarterly, vol. 31 (Mar. 1960), pp. 77-81.

Rasch, P. J., Cowell, H. S., Pierson, W. R., "The Correlation of the Bruce PFI with the Harvard Step Test," Revue Canadienne de Biologie, vol. 18 (Apr. 1959), pp. 77-82.

Richardson, J. R., "The Effect of Brief Isometric and Isotonic Exercise Programmes on the Development of Strength and Muscular Endurance," Unpublished Master's Thesis, University of Alberta, 1963.

Rodahl, K., Horvath, S. M., "Cardiac Performance," Muscle as a Tissue, New York: McGraw-Hill Book Company, Inc., 1962, pp. 243-58.

Russel, W. L., "A Study of the Relationship of Performance in Certain Generally Accepted Tests of Physical Fitness," Doctoral Thesis, Louisiana State University, 1952, Microcard.

Seltzer, C. C., "Anthropometric Characteristics and Physical Fitness," Research Quarterly, vol. 17 (Mar. 1946), pp. 10-20.

Seltzer, C. C., Brouha, L., "The Masculine Component and Physical Fitness," American Journal of Physical Anthropology, vol. 1 (Mar. 1943), pp. 95-108.

Schilling, J. A., Harvey, R. B., Becker, E. L., Velasquez, T., Wells, G., Balke, B., "Work Performance at Altitude After Adaptation in Man and Dog," Journal of Applied Physiology, vol. 8 (Jan. 1956), pp. 381-7.

Scott, M. G., Mordy, M., "Validation of Mass-Type Physical Tests with Tests of Work Capacity," Research Quarterly, vol. 16 (May 1945), pp. 128-38.

Shay, C. T., "Effects of Specific Sports Upon Fitness," College Physical Education Association, 60th Annual Proceedings, 1957, pp. 67-73.

Sloan, A. W., "A Modified Harvard Step Test for Women," Journal of Applied Physiology, vol. 14 (Nov. 1959), pp. 985-6.

Sloan, A. W., "Effect of Training on Physical Fitness of Women Students," Journal of Applied Physiology, vol. 16 (Jan. 1961), pp. 167-9.

Sloan, A. W., Keen, E. N., "Physical Fitness of Oarsmen and Rugby Players Before and After Training," Journal of Applied Physiology, vol. 14 (July 1959), pp. 635-6.

Smilie, K. M., (Programmer), Stepwise Regression - Revision 2, Programme No. 1620-019, University of Alberta Computing Centre, 1963.

Smilie, K. M., (Programmer), Simple Correlations, Programme No. 1620-013, University of Alberta Computing Centre, 1963.

Snellen, J. W., "External Work in Level and Grade Walking on a Motor Driven Treadmill," Journal of Applied Physiology, vol. 15 (Sept. 1960), pp. 759-63.

Steinhaus, A. H., "Chronic Effects of Exercise," Physiological Reviews, vol. 13 (1933), pp. 103-47.

Sterling, L. F., "A Factorial Analysis of Cardiovascular Variables," Doctoral Thesis, University of Illinois, 1960, Microcard.

Taddonio, D. A., Karpovich, P. V., "The Harvard Step Test as a Measure of Endurance in Running," Research Quarterly, vol. 22 (Oct. 1951), pp. 381-4.

Taylor, C., "Some Properties of Maximal and Submaximal Exercises with Reference to Physiological Variation and the Measurements of Exercise Tolerance," American Journal of Physiology, vol. 142 (Sept. 1944), pp. 200-12.

Taylor, C., "A Maximal Pack Test of Exercise Tolerance," Research Quarterly, vol. 15 (Dec. 1944), pp. 291-302.

Taylor, C., "Exercise" Annual Review of Physiology, vol. 7 (1945), pp. 599-617.

Taylor, H. L., Yangwang, R. L., Bloomquist, G., "The Standardization and Interpolation of Submaximal and Maximal Test of Working Capacity," Pediatrix, vol. 32 (1963), pp. 703-22.

Wahlund, H., "Determination of the Physical Working Capacity," Acta Medica Scandinavica Supplementum 215, (1948), p. 74.

Weiss, R. A., "Circulo-Respiratory Responses to Moderate (Submaximal) Exercise," College Physical Education Association, 60th Annual Proceedings, 1957, pp. 112-116.

Welch, G. E., Bruce, R. A., Bridges, W. C., Johnson, A. D., Lehmann, J. H., Nielsen, M., Glenn, D., "Comparison of a New Step Test with a Treadmill Test for the Evaluation of Cardio-respiratory Working Capacity," American Journal of Medical Sciences, vol. 223 (June 1952), pp. 607-17.

Weld, C. B., "Physical Fitness: The Step Test," Nova Scotia Medical Bulletin, vol. 25 (1946), pp. 157-62.

Wells, J. G., Balke, B., Van Fossan, W. D., "Lactic Acid Accumulation During Work. A Suggested Standardization of Work Classification," Journal of Applied Physiology, vol. 10 (Jan. 1957), pp. 51-55.

Williamson, K. R., "Quantitative Strength Changes Resulting from Varied Isometric Contractions," Unpublished Master's Thesis, University of Alberta, 1964.

Woodall, A. W., "The Construction of a Cardiovascular Test as a Measure of Physical Fitness," Master's Thesis, University of North Carolina, 1959, Microcard.

APPENDIX A

STATISTICAL TREATMENT

STATISTICAL TREATMENT

Test Reliabilities. Reliability coefficients were obtained using the Pearson product-moment method. The formula used was:

$$r = \frac{N \sum XY - \sum X \sum Y}{\sqrt{\left[N \sum X^2 - (\sum X)^2\right]\left[N \sum Y^2 - (\sum Y)^2\right]}} \qquad (1:92)$$

Where N = the number of subjects

X = the initial test score

Y = the retest score, and

$\sum$ = summation sign

Correlation Coefficients. Correlation coefficients, along with means, variances and standard deviations for sample one were calculated by an I.B.M. - 1620 Electronic Computor (program #1620-013) (2). This program provided the intercorrelation matrix of the seventy-seven variables involved.

Significance of a Correlation Coefficient. The significance of the correlation coefficients was tested using the formula

$$t = r\sqrt{\frac{N - 2}{1 - r^2}} \qquad (1:152)$$

With N - 2 degrees of freedom,

Where t = t ratio

r = the correlation coefficient between the variables under consideration, and

N = the number of subjects.

Multiple Regression Analysis. The multiple regression analysis of the specific terminal step test parameters to Balke treadmill test performance time was calculated by an I.B.M. - 1620 Electronic Computor (program #1620-019) (3).

To test the significance of the beta coefficients in the regression equations, the following formula was used

$$t = \frac{\text{Beta wt.}}{\text{St'd Error of Beta wt.}}$$

With $N - n - 1$ degrees of freedom.

Correlation coefficients, means, variances, standard deviations, standard errors and analysis of variances were also procured through the above program.

Validation of Multiple Regression Analysis. To validate the multiple regression analysis, standard errors of estimate for sample two were calculated using the formula

$$Sy.x = \sqrt{\frac{(Y - \hat{Y})^2}{N}} \qquad (1:107)$$

Where N = the number of subjects

Y = the observed treadmill perf. time

Y = the predicted treadmill perf. time from regression equations, and

Σ = summation sign.

Significance of the Difference Between Two Correlation Coefficients. To test the significance of the difference between two correlation coefficients, Fisher's Z_r transformation was utilized.

$$Z = \frac{Z_{r_1} - Z_{r_2}}{\sqrt{\frac{1}{N_1 - 3} + \frac{1}{N_2 - 3}}} \qquad (1:154)$$

Where Z = a unit-normal-curve deviate

Z_{r_1} & Z_{r_2} = values of Fisher's transformations for corresponding correlation coefficients

N_1 = the number of subjects utilized in determing r_1, and

N_2 = the number of subjects utilized in determing r_2.

Normative Table. A Normative table was established for performance time in the Balke Treadmill test and the Terminal Step test in standard score form (1:214).

The raw score mean (performance time) is assigned a standard score value of 50 which is the point of reference for all scores. A

score range of 100 is used which extends three standard deviations above and three standard deviations below the mean. The formula for one standard score increment is

$$\text{S.S.I.} = \frac{6 \times \sigma}{100} \text{ and}$$

for a standard score increment of five is

$$\text{S.S.I. of } 5 = \frac{6 \times \sigma}{100} \times 5$$

Where σ = the standard deviation of the raw scores.

REFERENCES

1. Ferguson, G. A., Statistical Analysis in Psychology and Education, Toronto: McGraw-Hill Book Company, Inc., 1959.

2. Smilie, K. M., (Programmer), Simple Correlations, Programme No. 1620-013, University of Alberta Computing Centre, 1963.

3. Smilie, K. M., (Programmer), Stepwise Regression-Revision 2, Programme No. 1620-019, University of Alberta Computing Centre, 1963.

APPENDIX B

SAMPLE DATA SHEETS

SAMPLE DATA SHEET

NAME ______________________________ DATE ____________

AGE ________________ (YR.) TEMP. ____________

PHONE ________________ B. PRESS ____________

WEIGHT (lbs.) ________ ________ M_x ________ = (÷ 2.2046) = KGMS.

HEIGHT (ins.) ________ ________ M_x ________ = (X 0.0254) = m.

LEG LENGTH (ins.) ________ ________ M_x ________ = (X 0.0254) = m.

LEG LENGTH/HEIGHT $\frac{LL\ (M_x)}{HT\ (M_x)}$ =

STRENGTH

PLANTAR FLEXORS

LT. ________ ________ M_x = ________ (÷ 2.2046) = kgms.

RT. ________ ________ M_x = ________ " =

____

KNEE EXTENSORS

LT. ________ ________ M_x = ________ " =

RT. ________ ________ M_x = ________ " =

____

HIP EXTENSORS

LT. ________ ________ M_x = ________ " =

RT. ________ ________ M_x = ________ " =

____

TOTAL ________

SAMPLE DATA SHEET

HEART RATE & PERF TIME

Name ______________

Age _____ Wt. _____ Ht. _____

Temp. _____ B. Press. _____

	PRE		EXERCISE																							
DATE TEST	1	2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
														POST												
														POST												
														POST												
														POST												
														POST												

APPENDIX C

RAW SCORES - SAMPLE ONE

SAMPLE ONE

SUBJECT	AGE (yrs)	WEIGHT (kgs)	HEIGHT (m)	LEG LENGTH (m)	LEG LENGTH/HEIGHT
1	18	72.199	1.765	0.890	0.504
2	18	66.905	1.710	0.886	0.518
3	18	47.551	1.569	0.754	0.481
4	21	65.544	1.780	0.890	0.500
5	19	66.262	1.683	0.846	0.502
6	18	67.207	1.664	0.857	0.515
7	19	72.802	1.708	0.862	0.504
8	20	52.465	1.721	0.899	0.522
9	18	63.805	1.810	0.918	0.507
10	18	81.004	1.873	0.978	0.522
11	18	73.180	1.740	0.913	0.525
12	17	72.272	1.708	0.876	0.512
13	18	54.582	1.689	0.898	0.532
14	18	59.496	1.651	0.847	0.513
15	17	55.641	1.721	0.919	0.534
16	18	74.465	1.806	0.955	0.529
17	18	65.431	1.721	0.887	0.516
18	19	67.132	1.778	0.914	0.514
19	20	73.482	1.655	0.825	0.499
20	19	80.210	1.719	0.884	0.514
21	19	77.186	1.772	0.892	0.504
22	18	59.572	1.676	0.844	0.503
23	18	64.713	1.689	0.862	0.510
24	20	66.225	1.683	0.862	0.512
25	19	67.359	1.731	0.892	0.515
26	19	66.225	1.702	0.901	0.529
27	18	65.394	1.702	0.874	0.513
28	18	65.998	1.753	0.903	0.515
29	18	59.572	1.907	1.036	0.543
30	17	78.699	1.702	0.852	0.501
31	21	78.321	1.746	0.899	0.515
32	18	66.528	1.797	0.918	0.511
33	18	54.885	1.721	0.825	0.479
34	18	84.596	1.791	0.947	0.529
35	18	61.614	1.721	0.890	0.517

SAMPLE ONE

SUBJECT	AGE (yrs)	WEIGHT (kgs)	HEIGHT (m)	LEG LENGTH (m)	LEG LENGTH/HEIGHT
36	19	87.770	1.803	0.905	0.502
37	19	75.751	1.911	0.935	0.489
38	19	64.864	1.797	0.943	0.525
39	18	82.252	1.753	0.882	0.503
40	18	78.926	1.797	0.926	0.515
41	19	66.225	1.848	0.964	0.522
42	19	70.988	1.765	0.938	0.531
43	18	84.066	1.816	0.948	0.522
44	27	82.555	1.784	0.924	0.518
45	20	63.957	1.746	0.887	0.508

SAMPLE ONE
STRENGTH (kgs)

SUBJECT	PLANTAR FLEXION Lt.	PLANTAR FLEXION Rt.	KNEE EXTENSION Lt.	KNEE EXTENSION Rt.	HIP EXTENSION Lt.	HIP EXTENSION Rt.	COMBINED STRENGTH
1	80.51	108.86	82.78	80.51	81.42	78.47	512.56
2	89.36	74.16	91.85	124.28	70.53	91.63	541.82
3	107.05	96.16	101.61	94.35	63.28	82.10	544.54
4	102.06	106.60	156.49	117.03	96.16	91.63	669.96
5	76.88	106.14	118.84	112.49	45.36	58.74	518.46
6	123.38	102.51	161.03	156.49	81.91	85.96	710.54
7	117.93	107.96	82.33	89.13	73.94	71.67	542.95
8	90.72	67.13	91.63	77.79	36.51	23.81	387.59
9	139.48	148.10	104.33	125.19	77.79	69.63	664.52
10	146.74	151.05	131.54	131.54	68.72	70.08	699.67
11	109.77	107.96	97.07	124.28	74.62	83.01	596.70
12	123.38	130.41	131.54	139.48	89.81	86.18	700.81
13	65.54	66.23	75.98	80.74	50.01	50.46	388.96
14	144.02	139.48	92.53	109.77	98.88	90.72	675.40
15	79.15	80.74	58.40	54.99	44.22	58.40	375.92
16	118.84	139.48	142.88	144.02	87.54	113.40	747.17
17	94.12	100.02	109.77	108.86	68.72	67.13	538.62
18	113.40	115.21	107.05	117.03	79.83	85.50	618.02
19	94.35	79.83	93.44	83.01	65.54	68.72	484.89
20	89.81	85.96	111.58	110.68	73.94	73.25	545.22
21	130.41	121.56	147.19	145.15	89.13	78.47	711.92
22	107.05	117.03	114.31	124.28	87.54	95.26	645.47
23	105.23	125.19	109.77	123.38	83.01	97.98	644.56
24	97.07	121.56	107.96	123.38	73.26	69.40	592.62
25	116.12	112.49	117.94	127.23	79.15	89.36	642.29
26	100.70	90.72	133.81	129.27	90.72	86.18	631.41
27	91.63	96.16	87.77	105.23	50.46	61.24	492.49
28	107.96	107.05	92.53	92.53	76.43	74.16	550.67
29	95.26	106.14	79.38	77.11	56.70	59.65	474.23
30	112.49	119.75	132.68	142.88	78.47	111.59	697.86
31	121.56	110.68	91.63	117.03	68.04	71.90	580.83
32	98.88	123.78	122.47	126.10	97.07	89.36	657.26
33	95.26	78.47	77.79	66.45	52.16	78.47	448.61
34	127.23	109.77	120.43	111.58	107.05	94.35	670.42
35	81.65	80.97	78.47	77.11	61.92	56.70	436.81

SAMPLE ONE
STRENGTH (kgs)

SUBJECT	PLANTAR FLEXION		KNEE EXTENSION		HIP EXTENSION		COMBINED STRENGTH
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	
36	72.58	87.54	146.74	153.09	70.99	71.89	602.83
37	90.04	79.38	102.51	104.33	74.84	109.77	560.88
38	106.14	88.91	74.16	76.43	57.61	63.50	466.75
39	121.56	103.42	120.66	111.58	80.74	85.28	623.24
40	103.42	116.12	130.18	126.10	96.16	121.56	693.55
41	121.56	80.74	120.66	103.42	74.62	74.62	575.61
42	159.89	149.69	151.05	158.53	85.28	95.25	799.69
43	125.19	136.08	123.38	126.10	79.15	89.81	679.71
44	111.58	117.94	161.93	127.24	61.01	89.13	668.83
45	107.05	140.84	125.19	130.41	80.74	82.33	666.56

SAMPLE ONE
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
1	76 75 74 82	137 149 163 166 170 173 173 180 149 130 127 118 115 110 100 97 97 94 98 104 99 100
2	97 97 92 95	147 160 173 173 177 180 166 152 140 132 127 120 115 114 115 110 110 112 110 110
3	60 65 65 65	160 173 177 180 157 124 105 83 96 83 93 77 88 79 73 85 95 76
4	89 95 95 96	163 177 180 149 130 123 112 101 101 94 96 99 103 104 102 104 104
5	89 85 89 85	129 149 157 166 170 180 160 155 144 135 130 130 120 118 118 118 124 114 118 114
6	87 109 113 114	166 170 170 173 177 180 157 155 140 142 136 142 125 127 122 128 128 126 120 122
7	117 120 124 124	154 166 177 180 157 142 128 130 133 127 127 127 122 127 128 125 127 125
8	109 103 109 110	144 160 177 180 157 142 130 124 124 120 124 112 117 117 113 112 112 113
9	74 73 76 78	160 166 170 177 180 144 117 110 109 100 109 100 93 92 92 92 88 97 91
10	101 109 104 109	173 177 180 149 130 128 124 115 115 120 120 120 117 118 115 115 114
11	68 76 74 82	152 170 180 140 128 112 107 99 100 98 95 99 103 90 94 83 98

SAMPLE ONE
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
12	97 96 101 100	160 177 180 152 144 120 120 114 116 109 109 107 107 101 109 107 105
13	96 96 88 88	160 166 177 180 157 133 120 115 105 99 112 100 99 97 103 101 93 91
14	92 84 91 103	157 173 177 180 163 149 144 135 130 125 125 124 117 118 114 118 113 115
15	70 80 84 78	135 163 170 177 180 152 126 116 110 100 105 98 98 98 96 97 92 95 97
16	71 71 86 92	163 171 177 180 142 122 112 98 97 87 91 91 98 97 100 91 94 88
17	74 76 77 76	140 155 163 166 173 173 177 180 152 133 122 114 110 112 105 104 103 104 100 100 101 101
18	75 82 85 81	149 163 173 180 144 133 117 113 100 101 96 97 100 98 98 99 97 92
19	117 124 120 117	149 157 177 180 163 155 149 144 140 137 135 133 130 130 128 130 130 130
20	89 93 103 91	147 160 170 171 173 180 160 155 140 137 130 125 124 124 122 122 117 120 115 117
21	90 96 96 110	147 163 166 175 177 180 152 142 130 127 117 118 115 117 113 113 114 124 117 113
22	81 82 81 87	144 158 160 170 180 144 127 115 113 109 109 103 110 109 100 110 103 109 103

SAMPLE ONE
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
23	83 76 83 83	130 144 155 163 173 180 147 142 137 130 122 117 114 113 114 110 105 114 109 104
24	103 103 112 110	160 177 180 149 124 120 118 115 114 117 104 107 103 105 107 105 103
25	57 66 53 50	144 157 169 169 173 180 149 128 124 118 98 101 100 104 96 96 104 105 98 91
26	80 80 78 90	163 173 180 155 142 133 118 114 105 100 107 98 99 104 100 100 100
27	91 99 96 96	140 166 173 180 157 144 125 128 127 118 112 112 114 114 111 111 112 109
28	90 83 92 87	163 163 166 171 173 180 149 133 124 125 115 115 115 110 113 101 109 104 104 100
29	92 94 92 92	149 163 173 180 142 120 118 113 110 114 113 109 108 101 108 105 103 110
30	83 75 89 94	163 180 149 130 121 113 110 103 103 104 103 105 109 99 101 103
31	96 109 84 94	152 166 173 180 157 140 122 124 114 114 113 109 107 107 109 99 104 110
32	75 73 82 73	149 163 173 180 152 121 100 89 92 88 88 90 90 98 82 83 83 90
33	100 109 105 103	166 170 180 149 142 128 125 118 118 114 114 114 113 120 113 115 114

SAMPLE ONE
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
34	95 96 94 99	166 177 180 160 147 130 124 114 115 118 109 109 110 107 114 112 113
35	83 87 83 71	137 155 166 166 170 173 177 180 152 124 114 112 104 109 105 98 99 105 105 101 100 100
36	96 86 93 93	145 160 170 177 180 160 144 130 130 117 119 119 115 117 117 113 115 118 114
37	100 94 81 94	157 173 180 147 130 122 117 103 101 94 107 88 100 100 101 105 103
38	83 87 90 88	142 155 160 166 173 173 177 177 180 149 140 130 127 122 118 118 114 115 117 113 109 104 112
39	88 82 78 85	173 177 180 140 124 115 107 100 103 100 99 101 100 97 100 94 97
40	94 101 94 101	173 180 173 155 144 135 130 122 124 127 112 117 114 115 124 113
41	92 88 84 91	140 155 158 166 173 155 144 130 124 125 127 124 115 114 117 114 113 110 103
42	97 98 96 98	140 152 166 169 173 173 177 180 155 135 127 120 118 117 117 112 114 112 109 110 109 110
43	120 114 120 130	173 177 180 163 149 140 135 124 130 128 128 122 124 125 122 122 122
44	109 117 115 114	163 173 180 170 149 128 135 133 130 127 114 124 117 113 114 117 118

SAMPLE ONE
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
45	74 75 76 76	144 152 157 164 166 173 177 180 144 133 127 113 112 100 100 100 104 98 98 97 109 95

SAMPLE ONE
TREADMILL TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
1	90 84 82 82	120 113 122 114 115 110 115 120 114 118 124 124 122 125 125 127 137 137 142 137 138 141 147 149 152 152 157 160 160 160 164 170 171 174 178 180 152 127 117 112 112 110 112 104 98 96 94 99 96 96
2	87 86 78 85	133 124 128 127 122 127 128 133 135 133 137 140 137 144 147 152 149 152 157 157 157 163 162 163 166 173 169 173 173 173 177 180 149 130 124 124 118 113 113 120 112 114 113 107 114 109
3	71 75 80 71	112 114 115 113 117 115 118 122 117 122 127 133 135 137 140 144 150 155 160 163 163 167 166 169 173 177 177 180 130 124 117 112 114 107 103 104 101 114 87 96 84 87
4	94 93 78 87	120 114 124 127 122 118 124 128 130 130 130 137 140 144 149 155 157 160 163 163 166 169 173 177 180 147 127 109 113 117 98 107 110 114 105 98 107 101 94
5	80 86 80 82	105 105 105 109 109 109 112 113 117 115 120 124 122 125 129 130 133 133 127 144 140 142 147 147 149 152 160 157 157 160 163 166 166 173 173 173 180 155 130 118 117 113 121 117 109 113 112 112 105 110 115
6	103 105 112 120	140 135 133 130 137 140 135 135 135 135 140 142 144 144 142 149 149 149 155 157 155 160 163 163 166 169 171 172 173 173 177 177 177 180 155 140 133 140 137 137 135 118 130 120 127 127 128 128
7	85 94 94 91	100 99 100 105 109 113 112 112 117 120 124 125 128 130 135 140 142 144 147 147 155 157 161 162 166 170 177 180 155 130 127 122 127 122 122 120 117 115 117 115 114 118

SAMPLE ONE
TREADMILL TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
8	98 96 103 94	124 120 127 122 120 124 123 128 127 129 135 135 140 140 142 142 149 152 152 157 162 164 167 170 177 175 177 180 155 144 142 120 130 130 124 133 127 125 122 125 120 117
9	87 90 89 92	109 105 110 103 110 109 113 109 112 120 117 118 127 124 140 137 142 144 146 149 157 155 157 162 160 163 166 166 166 173 173 176 177 180 150 133 128 117 118 112 110 110 106 112 104 109 103 100
10	83 95 87 90	124 120 115 117 115 120 124 124 124 133 127 127 133 133 137 144 140 144 152 152 156 156 156 163 166 170 171 174 177 180 149 130 122 125 127 118 105 117 117 125 115 122 109 112
11	90 82 92 93	114 118 122 125 127 128 120 128 133 130 128 135 144 144 144 155 155 159 161 163 166 170 173 177 180 152 130 128 120 125 109 109 112 114 105 98 97 103 101
12	100 84 99 100	120 114 116 121 120 120 124 120 125 127 129 124 135 136 135 140 143 144 147 149 149 155 155 160 163 166 170 177 180 148 140 133 124 127 122 120 120 114 112 113 112 105 113
13	85 92 82 81	112 112 109 109 112 110 118 120 117 116 124 109 125 127 130 133 135 137 142 140 149 147 140 152 160 158 163 165 165 166 169 171 177 177 180 140 130 124 117 120 122 114 112 114 98 103 109 114 104
14	80 82 80 78	118 114 115 112 116 118 120 124 117 126 130 128 135 141 140 144 144 147 155 160 160 163 169 173 173 177 180 149 142 131 125 117 115 105 112 107 107 105 99 105 110

SAMPLE ONE
TREADMILL TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
15	80 83 78 76	105 99 100 94 102 107 102 104 110 112 112 113 116 114 126 126 127 129 130 133 140 137 144 147 149 152 158 160 160 166 173 173 177 180 157 128 125 120 115 120 115 109 109 112 105 109 112 105
16	83 85 87 83	112 110 115 117 113 105 113 114 113 117 124 128 124 127 130 127 133 140 140 147 147 155 152 155 157 157 161 163 163 169 169 173 177 177 178 180 157 140 124 130 117 118 120 112 112 110 108 98 103 112
17	92 100 100 94	117 112 117 109 117 120 117 117 122 125 128 125 130 130 127 137 140 144 144 147 152 152 153 157 157 169 160 160 166 166 169 173 177 169 177 177 178 180 155 135 117 112 112 110 109 110 109 114 113 113 112 109
18	77 76 83 80	105 104 109 109 110 109 104 113 113 113 114 114 124 120 118 122 122 130 130 128 133 133 135 135 141 143 143 144 140 149 149 149 157 157 160 157 162 163 166 166 173 173 177 180 133 120 118 109 105 109 96 101 98 109 105 100 100 91
19	109 103 98 103	118 121 117 124 127 128 127 130 133 137 140 140 142 144 149 152 156 155 160 163 164 166 169 172 173 177 180 166 152 140 133 133 127 128 127 124 117 118 120 120 120
20	114 105 114 107	127 120 127 128 128 127 128 130 135 135 137 140 141 144 149 149 150 155 160 160 161 162 166 167 169 171 173 175 177 180 166 155 149 144 135 130 128 127 130 127 128 124 128 128

SAMPLE ONE
TREADMILL TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
21	90 73 77 85	112 105 105 112 109 114 116 114 122 124 124 124 130 133 132 135 137 140 144 147 147 149 155 155 160 160 163 163 166 163 169 170 172 173 173 177 180 152 127 130 114 109 110 113 109 120 113 114 117 104 110
22	68 80 91 72	109 104 107 115 112 110 112 117 113 118 119 121 126 127 128 133 136 140 147 147 155 152 157 160 166 166 169 173 173 177 180 155 128 127 117 115 105 112 120 118 112 104 110 106 109
23	72 87 87 88	108 103 105 100 110 104 109 105 110 114 117 115 112 120 120 122 125 126 127 133 129 133 137 137 147 147 149 155 155 155 163 166 169 173 177 180 147 142 137 128 127 124 117 120 120 117 113 114 113 107
24	82 76 73 78	115 118 117 114 114 114 120 124 125 125 128 124 135 136 137 144 143 152 152 155 157 160 168 166 169 173 177 180 149 118 103 115 115 105 104 103 101 96 92 103 95 93
25	67 75 68 67	107 106 105 105 107 110 114 118 118 124 120 125 128 128 133 130 138 138 144 144 147 152 157 157 155 160 163 163 166 166 166 166 170 170 173 177 180 157 144 124 124 112 94 107 107 99 103 99 96 99 94
26	92 92 96 93	117 110 117 118 117 124 124 124 127 127 129 129 135 135 140 140 149 144 147 150 149 152 157 157 163 165 163 173 173 173 180 144 135 115 109 118 118 118 118 115 114 107 112 113 109
27	103 103 97 99	123 127 128 127 130 135 135 140 144 142 144 149 152 155 155 157 160 160 160 163 166 166 169 170 173 173 177 180 149 130 125 122 110 114 120 120 112 104 115 117 112 112

SAMPLE ONE
TREADMILL TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
28	91 78 87 82	125 117 118 112 112 114 120 118 122 120 118 118 127
		130 137 137 142 144 142 143 147 152 152 155 157 160
		163 166 166 166 169 166 173 173 173 177 177 180 149
		135 128 118 110 112 110 110 101 110 110 112 109 105
29	94 87 87 95	120 115 118 115 117 116 116 120 120 126 124 130 128
		130 137 137 140 144 147 149 153 155 157 160 163 163
		163 166 170 173 180 137 130 128 104 115 122 117 114
		114 109 118 109 101 101
30	94 94 90 87	127 120 118 125 126 124 120 120 130 135 135 135 135
		142 147 147 152 149 155 163 160 166 171 173 177 180
		149 127 124 118 118 112 115 110 115 112 115 110 112
		118
31	100 104 104 100	122 118 120 124 125 126 130 133 135 137 135 140 144
		147 147 149 149 153 157 157 160 163 166 168 173 177
		177 180 157 140 137 140 127 127 122 124 122 112 115
		110 122 124
32	83 73 72 73	115 107 117 106 104 105 105 114 110 109 112 112 120
		124 127 127 135 135 150 157 159 152 163 162 162 166
		173 172 177 180 144 122 124 109 105 98 105 102 96
		98 92 97 93 88
33	101 98 105 96	115 112 116 103 114 112 114 114 115 117 124 124 120
		127 130 131 137 137 135 143 149 147 152 157 157 160
		163 160 169 173 173 177 180 142 136 127 130 127 122
		98 120 120 122 117 114 120 120

SAMPLE ONE
TREADMILL TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
34	68 70 78 82	118 113 113 113 114 117 114 114 120 125 122 125 127
		125 137 140 137 140 144 144 152 157 155 160 163 163
		173 173 173 180 144 122 110 114 113 114 105 96 100
		98 98 101 98 100
35	70 69 72 72	99 84 86 87 87 88 92 88 94 97 98 88 103
		104 109 109 112 113 118 117 124 124 125 130 128 130
		137 142 147 144 149 152 157 157 163 166 166 170 170
		170 173 173 180 166 137 135 120 124 113 110 109 109
		105 105 100 107 105
36	109 100 96 93	130 130 120 124 125 124 122 127 130 130 133 135 140
		140 142 147 149 152 155 155 157 160 163 166 166 169
		173 173 176 178 180 155 140 135 135 133 124 122 124
		113 117 115 122 114 112
37	96 90 92 92	109 110 103 110 105 112 116 114 117 114 124 120 124
		124 133 125 135 135 133 142 140 140 144 140 147 152
		159 160 163 163 166 173 177 180 149 133 125 122 125
		127 122 117 115 115 105 98 96 109
38	94 90 102 89	112 109 109 104 110 109 113 105 110 113 115 118 120
		117 122 128 127 127 127 127 127 130 135 135 137 142
		142 142 147 149 152 149 149 157 157 160 160 160 163
		166 170 173 170 173 173 177 180 155 144 140 133 127
		125 124 122 120 124 122 118 122 118
39	79 82 80 86	133 124 120 125 124 126 130 130 135 133 137 142 142
		149 149 157 160 162 169 171 173 173 180 149 130 125
		114 114 109 103 105 105 110 124 107 110 100

SAMPLE ONE
TREADMILL TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
40	95 89 96 97	128 125 128 130 130 130 130 133 135 135 140 142 147 149 149 157 157 166 163 166 173 171 173 180 157 140 127 123 127 118 114 117 114 117 115 115 104 109
41	94 99 100 94	118 120 125 124 120 124 128 128 127 133 133 128 130 136 142 133 147 149 145 152 155 155 155 155 155 163 159 163 164 166 166 173 170 173 173 173 157 135 124 133 127 117 124 115 114 117 114 113 112 112
42	112 94 98 105	124 117 110 117 117 117 119 117 120 124 125 130 130 133 133 135 142 142 144 144 147 147 149 155 157 157 163 166 166 170 170 173 173 177 177 177 180 144 135 124 120 117 124 114 117 114 114 110 110 114 114
43	98 105 118 112	142 144 144 144 142 142 140 140 146 147 144 148 152 149 156 157 155 155 157 163 163 170 169 170 170 173 180 149 130 127 117 119 135 118 122 124 112 117 118 118 117
44	99 109 99 89	113 125 122 120 120 121 125 122 125 130 130 128 124 130 137 141 142 144 152 152 154 155 160 158 166 166 169 171 175 175 177 180 160 142 128 125 125 115 124 125 115 122 114 103 114 112
45	68 66 67 65	109 104 103 99 103 98 104 105 109 107 115 114 113 109 120 120 122 120 124 122 130 128 130 133 140 144 144 144 149 149 155 163 160 163 166 166 173 173 173 173 177 180 140 128 110 105 103 100 94 93 95 94 94 90 97 93

SAMPLE ONE

SUBJECT	TREADMILL TEST		STEP TEST	
	PERFORMANCE TIME (min.)	EXTERNAL WORK (mkg/min.)	PERFORMANCE TIME (min.)	EXTERNAL WORK (mkg.)
1	17.83	1119.25	4.12	4511.28
2	15.62	915.16	2.88	2922.95
3	13.63	563.70	1.67	1207.79
4	12.38	717.23	1.09	1065.65
5	18.27	1087.64	2.99	3029.49
6	16.52	980.58	2.82	2867.86
7	13.88	863.05	1.89	2108.05
8	13.73	621.96	1.75	1385.92
9	16.63	930.94	2.06	2009.60
10	14.81	1034.15	1.10	1357.95
11	12.37	800.79	1.36	1524.19
12	14.08	922.67	1.37	1505.28
13	17.11	846.15	2.09	1746.84
14	13.40	705.31	1.82	1662.32
15	16.93	811.82	2.32	1978.59
16	18.14	1222.28	1.80	2042.72
17	19.56	1133.66	3.64	3656.28
18	21.86	1285.57	2.07	2114.39
19	13.61	871.11	2.06	2314.39
20	15.13	1097.15	2.78	3381.97
21	18.39	1266.95	2.71	3176.05
22	15.19	814.86	2.36	2118.38
23	17.98	1003.20	2.81	2761.43
24	13.72	785.08	1.30	1312.05
25	18.52	1105.64	3.09	3182.31
26	15.34	905.86	1.41	1412.98
27	13.67	775.23	1.90	1893.55
28	18.81	1083.30	2.92	2950.37
29	15.52	814.86	1.70	1543.39
30	12.79	861.19	0.97	1159.39

SAMPLE ONE

SUBJECT	TREADMILL TEST		STEP TEST	
	PERFORMANCE TIME (min.)	EXTERNAL WORK (mkg/min.)	PERFORMANCE TIME (min.)	EXTERNAL WORK (mkg.)
31	13.68	928.47	1.73	2068.93
32	14.86	849.34	1.92	1926.38
33	16.20	800.79	1.36	864.33
34	15.12	1157.15	1.17	1718.99
35	21.58	1179.90	3.75	3505.59
36	15.26	1200.96	2.30	3076.51
37	16.77	1105.24	1.37	1577.74
38	23.55	1360.44	4.20	4151.81
39	11.50	825.06	1.26	1462.44
40	12.02	863.67	0.89	1082.55
41	17.60	1026.64	2.46	2489.53
42	18.29	1165.21	3.63	3931.30
43	13.12	996.58	1.35	1708.22
44	15.70	1129.23	1.35	1677.52
45	20.78	1166.45	3.91	3801.35

INTERCORRELATION MATRIX BETWEEN SELECTED
ANTHROPOMETRICAL AND PHYSIOLOGICAL VARIABLES
OF SAMPLE ONE (N = 45)

VARIABLES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 - AGE	.211	.097	.054	-.034	.008	-.007	.322	.087	-.129	-.061	.072	.205	.312	.105	.034	-.104	.132
2 - WEIGHT		.430	.328	.036	.273	.297	.512	.521	.406	.421	.515	.313	.262	.246	.363	.405	.430
3 - HEIGHT			.881	.297	.166	.182	.159	.080	.126	.140	.178	.170	.079	.071	.152	.094	.095
4 - LEG LENGTH				.709	.170	.179	.093	.059	.054	-.008	.119	.125	.068	.073	.167	.110	.091
5 - LEG LENGTH/HEIGHT RATIO					.111	.080	-.051	.008	-.043	-.203	-.014	.019	.025	.053	.122	.101	.055
6 - LEFT PLANTAR FLEXION STRENGTH						.730	.422	.500	.522	.374	.737	-.028	-.022	.110	.192	.168	.139
7 - RIGHT PLANTAR FLEXION STRENGTH							.469	.607	.552	.443	.797	-.199	-.208	-.149	-.064	.020	.008
8 - LEFT KNEE EXTENSOR STRENGTH								.852	.537	.515	.822	.174	.142	.101	.216	.336	.351
9 - RIGHT KNEE EXTENSOR STRENGTH									.591	.569	.885	.104	.039	.053	.190	.339	.325
10 - LEFT HIP EXTENSOR STRENGTH										.745	.793	-.174	-.317	-.174	-.056	.157	.023
11 - RIGHT HIP EXTENSOR STRENGTH											.735	-.093	-.123	-.049	-.009	.154	.137
12 - COMBINED ANKLE, KNEE AND HIP STRENGTH												-.025	-.079	-.010	.113	.256	.225
13 - TREADMILL TEST PRE-EXERCISE HEART RATE 0.5 MIN.													.784	.758	.831	.551	.596
14 - TREADMILL TEST PRE-EXERCISE HEART RATE 1.0 MIN.														.833	.799	.470	.608
15 - TREADMILL TEST PRE-EXERCISE HEART RATE 1.5 MIN.															.873	.490	.571
16 - TREADMILL TEST PRE-EXERCISE HEART RATE 2.0 MIN.																.620	.645
17 - TREADMILL EXERCISE HEART RATE 0.5 MIN.																	.895
18 - TREADMILL EXERCISE HEART RATE 1.0 MIN.																	
19 - TREADMILL EXERCISE HEART RATE 1.5 MIN.																	
20 - TREADMILL EXERCISE HEART RATE 2.0 MIN.																	
21 - TREADMILL EXERCISE HEART RATE 2.5 MIN.																	
22 - TREADMILL EXERCISE HEART RATE 3.0 MIN.																	
23 - TREADMILL EXERCISE HEART RATE 3.5 MIN.																	
24 - TREADMILL EXERCISE HEART RATE 4.0 MIN.																	
25 - TREADMILL EXERCISE HEART RATE 4.5 MIN.																	
26 - TREADMILL EXERCISE HEART RATE 5.0 MIN.																	
27 - TREADMILL EXERCISE HEART RATE 5.5 MIN.																	
28 - TREADMILL EXERCISE HEART RATE 6.0 MIN.																	
29 - TREADMILL EXERCISE HEART RATE 6.5 MIN.																	
30 - TREADMILL EXERCISE HEART RATE 7.0 MIN.																	
31 - TREADMILL EXERCISE HEART RATE 7.5 MIN.																	
32 - TREADMILL EXERCISE HEART RATE 8.0 MIN.																	
33 - TREADMILL EXERCISE HEART RATE 8.5 MIN.																	
34 - TREADMILL EXERCISE HEART RATE 9.0 MIN.																	
35 - TREADMILL EXERCISE HEART RATE 9.5 MIN.																	
36 - TREADMILL EXERCISE HEART RATE 10.0 MIN.																	
37 - TREADMILL EXERCISE HEART RATE 10.5 MIN.																	
38 - TREADMILL EXERCISE HEART RATE 11.0 MIN.																	
39 - TREADMILL EXERCISE HEART RATE 11.5 MIN.																	
40 - TREADMILL POST-EXERCISE HEART RATE 0.5 MIN.																	
41 - TREADMILL POST-EXERCISE HEART RATE 1.0 MIN.																	
42 - TREADMILL POST-EXERCISE HEART RATE 1.5 MIN.																	
43 - TREADMILL POST-EXERCISE HEART RATE 2.0 MIN.																	
44 - TREADMILL POST-EXERCISE HEART RATE 2.5 MIN.																	
45 - TREADMILL POST-EXERCISE HEART RATE 3.0 MIN.																	
46 - TREADMILL POST-EXERCISE HEART RATE 3.5 MIN.																	
47 - TREADMILL POST-EXERCISE HEART RATE 4.0 MIN.																	
48 - TREADMILL POST-EXERCISE HEART RATE 4.5 MIN.																	
49 - TREADMILL POST-EXERCISE HEART RATE 5.0 MIN.																	
50 - TREADMILL POST-EXERCISE HEART RATE 5.5 MIN.																	
51 - TREADMILL POST-EXERCISE HEART RATE 6.0 MIN.																	
52 - TREADMILL POST-EXERCISE HEART RATE 6.5 MIN.																	
53 - TREADMILL POST-EXERCISE HEART RATE 7.0 MIN.																	
54 - TREADMILL TEST PERFORMANCE TIME																	
55 - TREADMILL TEST EXTERNAL WORK																	
56 - STEP TEST PRE-EXERCISE HEART RATE 0.5 MIN.																	
57 - STEP TEST PRE-EXERCISE HEART RATE 1.0 MIN.																	
58 - STEP TEST PRE-EXERCISE HEART RATE 1.5 MIN.																	
59 - STEP TEST PRE-EXERCISE HEART RATE 2.0 MIN.																	
60 - STEP TEST EXERCISE HEART RATE 0.5 MIN.																	
61 - STEP TEST EXERCISE HEART RATE 1.0 MIN.																	
62 - STEP TEST POST-EXERCISE HEART RATE 0.5 MIN.																	
63 - STEP TEST POST-EXERCISE HEART RATE 1.0 MIN.																	
64 - STEP TEST POST-EXERCISE HEART RATE 1.5 MIN.																	
65 - STEP TEST POST-EXERCISE HEART RATE 2.0 MIN.																	
66 - STEP TEST POST-EXERCISE HEART RATE 2.5 MIN.																	
67 - STEP TEST POST-EXERCISE HEART RATE 3.0 MIN.																	
68 - STEP TEST POST-EXERCISE HEART RATE 3.5 MIN.																	
69 - STEP TEST POST-EXERCISE HEART RATE 4.0 MIN.																	
70 - STEP TEST POST-EXERCISE HEART RATE 4.5 MIN.																	
71 - STEP TEST POST-EXERCISE HEART RATE 5.0 MIN.																	
72 - STEP TEST POST-EXERCISE HEART RATE 5.5 MIN.																	
73 - STEP TEST POST-EXERCISE HEART RATE 6.0 MIN.																	
74 - STEP TEST POST-EXERCISE HEART RATE 6.5 MIN.																	
75 - STEP TEST POST-EXERCISE HEART RATE 7.0 MIN.																	
76 - STEP TEST PERFORMANCE TIME																	
77 - STEP TEST EXTERNAL WORK																	

VARIABLES	19	20	21	22	23	24	25	26	27	28	29	30
1	.091	.116	.058	.056	.149	.113	.114	.122	.116	.098	.010	.036
2	.288	.488	.397	.399	.390	.310	.464	.461	.378	.388	.353	.339
3	.078	.074	-.063	-.032	-.000	-.051	-.010	.010	-.090	-.048	-.088	-.138
4	.109	.078	-.040	.004	.006	-.038	.003	.035	-.105	-.068	-.077	-.147
5	.116	.053	.022	.068	.024	.009	.032	.067	-.066	-.072	-.011	-.082
6	.131	.168	.159	.176	.202	.088	.098	.259	.104	.185	.183	.169
7	.016	.021	.006	-.094	-.043	-.081	-.084	.029	-.098	.003	-.013	-.040
8	.309	.429	.323	.274	.316	.253	.292	.309	.282	.302	.250	.260
9	.266	.404	.322	.278	.291	.264	.308	.311	.267	.298	.307	.297
10	.100	.179	.085	.037	.052	.055	.035	.070	.020	.063	.099	.106
11	.129	.238	.172	.091	.107	.087	.097	.106	.129	.187	.076	.137
12	.210	.316	.236	.172	.209	.152	.172	.241	.161	.230	.200	.204
13	.593	.576	.616	.621	.612	.530	.592	.563	.609	.546	.535	.547
14	.572	.560	.660	.660	.667	.565	.598	.640	.666	.579	.509	.535
15	.579	.556	.663	.654	.610	.477	.532	.555	.575	.519	.493	.462
16	.637	.641	.735	.747	.702	.569	.659	.661	.667	.618	.606	.584
17	.868	.825	.828	.811	.816	.782	.790	.771	.774	.748	.735	.745
18	.916	.890	.916	.893	.905	.883	.871	.860	.875	.833	.810	.804
19		.891	.903	.855	.859	.881	.831	.820	.828	.821	.792	.798
20			.934	.905	.912	.922	.923	.905	.904	.889	.894	.894
21				.948	.915	.906	.920	.919	.926	.914	.896	.889
22					.938	.919	.953	.945	.931	.901	.922	.903
23						.938	.938	.937	.945	.886	.895	.908
24							.937	.915	.934	.904	.932	.940
25								.952	.937	.915	.936	.932
26									.936	.917	.918	.922
27										.935	.905	.931
28											.909	.919
29												.961

VARIABLES	31	32	33	34	35	36	37	38	39	40	41
1	.079	.074	.067	.074	[illegible]	.057	[illegible]	.030	.068	.228	.214
2	.366	.374	.308	.306	[illegible]	.304	[illegible]	.301	.281	.337	.125
3	-.013	-.125	-.103	-.074	[illegible]	-.126	[illegible]	-.117	-.149	-.013	-.084
4	-.037	-.118	-.143	-.106	[illegible]	-.172	[illegible]	-.131	-.181	.022	-.037
5	-.049	-.043	-.127	-.095	[illegible]	-.161	[illegible]	-.081	-.134	.072	.064
6	.171	.171	.145	.152	[illegible]	.187	[illegible]	.213	.167	-.132	-.009
7	-.051	-.005	-.070	-.039	[illegible]	.016	[illegible]	.033	.022	-.197	-.199
8	.223	.235	.252	.238	[illegible]	.286	[illegible]	.257	.239	.024	.025
9	.220	.251	.225	.224	[illegible]	.270	[illegible]	.252	.229	-.033	-.030
10	.073	.099	.102	.116	[illegible]	.129	[illegible]	.167	.162	-.127	-.144
11	.119	.103	.126	.134	.150	.183	[illegible]	.158	.142	-.122	-.080
12	.167	.187	.171	.178	[illegible]	.232	[illegible]	.230	.205	-.114	-.083
13	.525	.474	.533	.479	.414	.416	.365	.360	.357	.278	.472
14	.540	.491	.513	.455	.426	.442	.406	.388	.367	.354	.503
15	.437	.406	.421	.382	.324	.338	.310	.311	.261	.292	.527
16	.557	.537	.535	.488	.433	.440	.398	.406	.357	.237	.437
17	.715	.722	.698	.664	.677	.640	.597	.639	.594	.021	.160
18	.792	.789	.770	.751	.733	.724	.676	.709	.663	.025	.170
19	.768	.756	.771	.763	.726	.715	.675	.717	.674	-.008	.135
20	.858	.846	.850	.845	.820	.817	.760	.801	.749	.108	.152
21	.845	.869	.848	.829	.809	.796	.750	.783	.737	.081	.232
22	.875	.883	.865	.831	.810	.803	.764	.786	.748	.129	.213
23	.885	.863	.870	.840	.815	.806	.755	.776	.731	.126	.269
24	.887	.880	.892	.890	.869	.853	.823	.836	.810	.047	.139
25	.915	.911	.891	.866	.829	.826	.784	.808	.775	.138	.163
26	.919	.904	.886	.867	.860	.850	.813	.840	.795	.168	.224
27	.891	.874	.886	.862	.838	.849	.796	.814	.779	.141	.262
28	.897	.889	.895	.877	.845	.860	.802	.831	.801	.092	.206
29	.917	.938	.922	.926	.899	.883	.864	.882	.849	.082	.145
30	.930	.940	.952	.949	.925	[illegible]	[illegible]	.912	.894	.100	.177
31		.937	.958	.932	.899	[illegible]	[illegible]	[illegible]	.885	.114	.163
32			.944	.945	.943	[illegible]	.914	.925	.903	.087	.104
33				.968	.940	[illegible]	.927	.934	.924	.081	.141
34					.960	[illegible]	.955	.956	.934	.075	.101
35						[illegible]	.952	.957	.944	.082	.110
36							.961	.973	.970	.085	.107
37								.975	.963	.075	.056
38									.973	.073	.070
39										.095	.048
40											.626

25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
.114	.122	.116	.098	.010	.036	.079	.074	.067	.074	.100	.057	.052	.030	.068	.228	.214	-.002	.123	.141	-.032	.190	.241	.117	.162	.041	-.062	.126	.066	-.004	.141	.321	.393	.286	.259	.026	-.000	.352	.220	.150	.251	.278	.234	.257	.128	.275	.211	.177	.176	.253	.259	-.072	-.010
.464	.461	.378	.388	.353	.339	.366	.374	.308	.306	.330	.304	.251	.301	.281	.337	.125	.091	.266	.217	.172	.236	.124	.148	.120	.301	.170	.157	.278	-.241	.451	.338	.290	.271	.375	.326	.292	.214	.295	.262	.347	.212	.260	.251	.363	.293	.391	.296	.346	.313	.409	-.234	.047
-.010	.010	-.090	-.048	-.088	-.138	-.013	-.125	-.103	-.074	-.135	-.126	-.102	-.117	-.149	-.013	-.084	-.032	-.078	-.010	.071	.034	-.010	-.030	.066	.119	-.003	-.121	-.058	.148	.419	.148	.082	.003	.092	.153	.098	-.213	-.217	-.121	-.039	-.186	-.053	-.069	.027	-.090	.016	.015	.057	-.047	.059	-.124	-.013
.003	.035	-.105	-.068	-.077	-.147	-.037	-.118	-.143	-.106	-.152	-.172	-.133	-.131	-.181	.022	-.037	-.093	-.031	.149	.127	.011	.004	.010	.154	.035	.002	-.014	.198	.401	.401	.106	.071	.022	.080	.059	.027	-.137	-.166	-.071	.002	-.125	.004	.028	.056	-.009	.048	.048	-.047	-.113	.063	-.039	.048
.032	.067	-.066	-.072	-.011	-.082	-.049	-.043	-.127	-.095	-.085	-.161	-.107	-.081	-.134	.072	.064	.046	-.053	-.029	.188	.204	.046	.054	-.089	.127	.083	.193	.053	.171	.184	-.003	.030	.045	.036	-.078	-.059	.030	-.030	.016	.054	.004	.067	.144	.063	.094	.062	.052	-.020	-.183	.028	.093	.107
.098	.259	.104	.185	.183	.169	.171	.171	.145	.152	.208	.187	.192	.213	.167	-.132	-.009	-.028	.055	-.042	-.025	-.132	-.070	.011	.132	.075	.011	-.042	.083	-.104	.102	.055	.090	.092	.247	.376	.289	-.094	-.023	.004	.026	.033	.103	.123	.146	.144	.135	.074	.125	.111	.101	-.167	-.096
-.084	.029	-.098	.003	-.013	-.040	-.051	-.005	-.070	-.039	.016	.016	-.001	.033	.022	-.197	-.199	-.248	-.215	-.324	-.247	-.314	-.302	-.257	-.203	-.214	-.232	-.322	-.184	-.037	.173	-.111	-.138	-.015	.079	.236	.173	-.204	-.212	-.116	-.123	-.119	-.094	-.097	-.044	-.015	-.079	-.102	-.088	-.010	-.077	-.083	-.005
.292	.309	.282	.302	.250	.260	.223	.235	.252	.238	.278	.286	.217	.257	.239	.024	.025	-.190	.044	.040	-.090	.101	-.021	.097	.122	.064	.081	-.036	.061	-.143	.257	.035	.040	.129	.216	.325	.268	.143	.183	.126	.062	.069	.078	.025	.106	.132	.168	.101	.159	.206	.102	-.190	-.041
.308	.311	.267	.298	.307	.297	.220	.251	.225	.224	.274	.270	.192	.252	.229	-.033	-.030	-.131	.084	-.024	-.105	.041	-.041	.031	-.001	.006	.013	-.058	.059	-.135	.262	-.067	-.081	-.000	.123	.232	.207	.040	.120	.069	.059	.013	.013	-.038	.082	.067	.097	.019	.074	.091	.020	-.118	.039
.035	.070	.020	.063	.099	.106	.073	.099	.102	.116	.180	.129	.109	.167	.162	-.127	-.144	-.263	-.139	-.203	-.327	-.229	-.346	-.265	-.294	-.280	-.250	-.359	-.243	-.155	.160	-.148	-.200	-.136	.019	.344	.283	-.062	-.006	.012	-.086	-.137	-.147	-.192	-.018	-.164	-.079	-.154	-.010	-.038	-.081	-.148	-.022
.097	.106	.129	.187	.076	.137	.119	.103	.126	.134	.150	.183	.108	.158	.142	-.122	-.080	-.229	.010	-.100	-.198	-.134	-.187	-.138	-.073	-.171	-.319	-.291	-.093	-.171	.143	-.155	-.178	-.159	.006	.385	.359	.008	.031	.032	-.082	-.116	-.201	-.249	-.022	-.177	-.108	-.127	-.074	-.009	-.106	-.264	-.160
.172	.241	.161	.230	.200	.204	.167	.187	.171	.178	.237	.232	.176	.230	.205	-.114	-.083	-.219	-.022	-.123	-.193	-.118	-.182	-.087	-.047	-.089	-.122	-.211	-.049	-.155	.236	-.069	-.083	-.000	.157	.389	.324	-.026	.029	.032	-.014	-.040	-.036	-.073	.060	.019	.044	-.023	.050	.088	.003	-.202	-.056
.592	.563	.609	.546	.535	.547	.525	.474	.533	.479	.414	.416	.365	.360	.357	.278	.472	.452	.489	.549	.597	.618	.673	.610	.496	.589	.627	.595	.640	-.247	.008	.497	.520	.522	.512	.101	.089	.347	.444	.356	.461	.476	.488	.441	.469	.445	.527	.425	.407	.380	.546	-.099	.014
.598	.640	.666	.579	.509	.535	.540	.491	.513	.455	.426	.442	.406	.388	.367	.354	.503	.412	.580	.641	.649	.672	.772	.772	.619	.663	.677	.740	.728	-.292	-.089	.516	.566	.517	.527	.130	.090	.424	.485	.424	.531	.551	.562	.520	.530	.532	.586	.548	.442	.461	.572	-.181	-.104
.532	.555	.575	.519	.493	.462	.437	.406	.421	.382	.324	.338	.310	.311	.261	.292	.527	.542	.573	.665	.761	.654	.767	.762	.684	.698	.706	.724	.781	-.194	.006	.457	.497	.505	.530	.178	.104	.313	.511	.378	.488	.523	.556	.512	.546	.524	.579	.503	.439	.443	.552	-.128	-.058
.659	.661	.667	.618	.606	.584	.557	.537	.535	.488	.433	.440	.398	.406	.357	.237	.437	.444	.508	.638	.762	.649	.659	.739	.553	.708	.720	.669	.720	-.295	-.010	.524	.593	.574	.615	.234	.172	.302	.527	.455	.552	.544	.622	.533	.593	.524	.635	.534	.531	.473	.632	-.183	-.071
.790	.771	.774	.748	.735	.745	.715	.722	.698	.664	.677	.640	.597	.639	.594	.021	.160	.164	.253	.270	.357	.269	.320	.332	.236	.460	.496	.390	.357	-.470	-.148	.349	.305	.340	.427	.440	.342	.310	.375	.366	.344	.339	.359	.357	.377	.373	.365	.297	.335	.275	.374	-.217	-.103
.871	.860	.875	.833	.810	.804	.792	.789	.770	.751	.733	.724	.675	.709	.663	.025	.170	.115	.308	.325	.382	.343	.396	.353	.264	.406	.446	.354	.351	-.529	-.180	.437	.418	.427	.524	.460	.398	.415	.444	.388	.401	.422	.416	.452	.415	.448	.425	.333	.387	.354	.415	-.349	-.226
.831	.820	.828	.821	.792	.798	.768	.756	.771	.763	.726	.715	.675	.717	.674	-.008	.135	.077	.217	.233	.284	.289	.364	.319	.215	.328	.400	.311	.274	-.523	-.261	.316	.313	.357	.440	.390	.334	.364	.392	.314	.286	.354	.331	.331	.297	.347	.332	.221	.265	.221	.315	-.309	-.217
.923	.905	.904	.889	.894	.894	.858	.846	.850	.845	.820	.817	.760	.801	.749	.108	.152	.119	.267	.312	.306	.397	.425	.434	.244	.388	.414	.306	.364	-.633	-.222	.402	.387	.383	.522	.433	.433	.369	.442	.358	.341	.367	.340	.350	.382	.383	.400	.320	.360	.323	.393	-.432	-.285
.920	.919	.926	.914	.896	.889	.845	.869	.848	.829	.809	.796	.750	.783	.737	.081	.232	.188	.345	.387	.401	.405	.457	.484	.304	.461	.507	.427	.437	-.614	-.276	.360	.394	.406	.513	.409	.387	.377	.499	.414	.411	.447	.429	.423	.432	.450	.356	.402	.363	.363	.441	-.382	-.263
.953	.945	.931	.901	.922	.903	.875	.883	.865	.831	.810	.803	.764	.786	.748	.129	.213	.194	.335	.391	.421	.443	.488	.497	.356	.505	.556	.457	.473	-.622	-.287	.418	.467	.424	.546	.400	.421	.444	.542	.442	.466	.483	.492	.470	.506	.464	.505	.401	.456	.396	.502	-.407	-.288
.938	.937	.945	.886	.895	.908	.885	.863	.870	.840	.815	.806	.755	.776	.731	.126	.269	.165	.373	.386	.388	.441	.503	.477	.328	.481	.522	.423	.452	-.602	-.270	.468	.484	.409	.547	.458	.421	.437	.514	.451	.467	.489	.465	.478	.453	.454	.399	.450	.405	.449	.449	-.386	-.271
.937	.915	.934	.904	.932	.940	.887	.880	.892	.890	.869	.853	.823	.836	.810	.047	.139	.074	.266	.261	.236	.313	.403	.345	.175	.317	.394	.283	.285	-.682	-.395	.365	.395	.321	.447	.391	.400	.402	.430	.356	.344	.377	.332	.357	.369	.353	.349	.283	.340	.292	.346	-.431	-.328
	.952	.937	.915	.936	.932	.915	.911	.891	.866	.829	.826	.784	.808	.775	.138	.163	.120	.287	.297	.299	.371	.429	.429	.238	.448	.484	.395	.393	-.654	-.277	.423	.449	.391	.502	.382	.419	.395	.490	.406	.429	.418	.404	.403	.442	.418	.441	.363	.407	.359	.444	-.429	-.291
		.936	.917	.918	.922	.919	.904	.886	.867	.860	.850	.813	.840	.795	.168	.224	.157	.330	.343	.306	.383	.464	.452	.310	.463	.515	.390	.425	-.672	-.291	.428	.457	.401	.531	.404	.431	.414	.464	.419	.443	.449	.453	.475	.481	.471	.467	.403	.452	.410	.480	-.452	-.313
			.935	.905	.931	.891	.874	.886	.862	.838	.849	.796	.814	.779	.141	.262	.155	.353	.386	.378	.426	.492	.481	.310	.474	.493	.400	.464	-.675	-.343	.465	.467	.426	.563	.388	.404	.463	.539	.480	.452	.514	.439	.464	.485	.453	.476	.401	.466	.450	.473	-.422	-.306
				.909	.919	.897	.889	.895	.877	.845	.860	.802	.831	.801	.092	.206	.118	.300	.279	.285	.352	.422	.417	.305	.425	.417	.321	.384	-.668	-.326	.317	.356	.323	.458	.342	.367	.351	.451	.404	.354	.414	.352	.348	.398	.400	.400	.328	.374	.383	.426	-.394	-.270
					.961	.917	.938	.922	.926	.899	.883	.864	.882	.849	.082	.145	.129	.247	.282	.248	.305	.394	.377	.202	.340	.445	.271	.310	-.318	-.397	.333	.370	.324	.453	.436	.487	.344	.381	.300	.302	.315	.300	.327	.355	.312	.355	.258	.320	.290	.353	-.473	-.358
						.930	.940	.952	.949	.925	.936	.890	.912	.894	.100	.177	.159	.294	.300	.221	.311	.427	.398	.229	.377	.429	.296	.342	-.770	-.456	.360	.369	.327	.457	.406	.465	.373	.405	.322	.315	.360	.315	.346	.367	.344	.373	.276	.344	.294	.364	-.491	-.383
							.937	.958	.932	.899	.926	.906	.914	.885	.114	.163	.121	.260	.293	.229	.325	.395	.364	.220	.338	.394	.271	.315	-.792	-.465	.393	.380	.337	.456	.477	.525	.388	.361	.308	.302	.329	.304	.344	.348	.309	.339	.271	.295	.309	.362	-.557	-.445
								.944	.945	.943	.921	.914	.925	.903	.087	.104	.080	.214	.289	.173	.231	.357	.346	.204	.328	.414	.271	.274	-.802	-.472	.375	.407	.376	.479	.502	.549	.385	.372	.303	.308	.341	.318	.362	.350	.358	.364	.258	.322	.307	.397	-.532	-.422
									.968	.940	.952	.927	.934	.924	.081	.141	.081	.198	.281	.142	.285	.372	.318	.199	.285	.374	.216	.246	-.817	-.525	.319	.312	.272	.398	.453	.492	.330	.305	.239	.216	.285	.244	.271	.271	.247	.277	.186	.244	.236	.296	-.525	-.427
										.960	.958	.955	.956	.934	.075	.101	.062	.204	.272	.109	.228	.339	.281	.196	.250	.345	.146	.185	-.818	-.522	.301	.311	.278	.394	.477	.530	.321	.261	.188	.177	.243	.208	.267	.234	.234	.242	.144	.219	.216	.254	-.568	-.467
											.948	.952	.957	.944	.082	.110	.082	.190	.262	.051	.197	.308	.263	.160	.223	.312	.142	.161	-.830	-.521	.264	.299	.258	.373	.508	.545	.317	.218	.150	.148	.212	.179	.242	.210	.225	.217	.114	.213	.185	.248	-.536	-.430
												.961	.973	.970	.085	.107	.085	.196	.260	.103	.225	.332	.309	.216	.250	.301	.133	.215	-.877	-.577	.294	.273	.269	.396	.492	.564	.324	.251	.183	.145	.227	.189	.245	.236	.226	.252	.146	.207	.207	.259	-.628	-.534
													.975	.963	.075	.056	.054	.151	.241	.054	.145	.290	.259	.157	.211	.299	.120	.164	-.885	-.625	.305	.321	.283	.390	.537	.590	.314	.190	.110	.110	.185	.169	.250	.211	.210	.224	.136	.176	.203	.239	-.649	-.575
														.973	.073	.070	.046	.158	.227	.056	.174	.280	.246	.135	.200	.273	.104	.167	-.872	-.575	.286	.279	.280	.392	.543	.598	.314	.205	.122	.104	.179	.155	.238	.198	.207	.223	.126	.180	.178	.234	-.632	-.538
															.095	.048	.050	.136	.198	.002	.159	.263	.229	.105	.179	.257	.098	.139	-.897	-.618	.268	.262	.269	.373	.497	.578	.288	.177	.104	.097	.168	.147	.207	.192	.183	.218	.114	.166	.144	.240	-.629	-.542
																.626	.523	.612	.515	.261	.585	.467	.437	.339	.423	.344	.494	.547	.001	.221	.203	.256	.243	.175	-.225	-.205	.303	.328	.343	.465	.403	.476	.390	.437	.396	.506	.468	.379	.343	.446	.211	.304
																	.774	.733	.683	.511	.604	.691	.573	.591	.588	.446	.620	.635	.046	.145	.192	.219	.192	.126	-.109	-.227	.328	.481	.494	.522	.478	.456	.463	.498	.467	.490	.427	.421	.374	.413	.191	.234
																		.674	.658	.602	.615	.729	.657	.618	.670	.555	.638	.645	-.002	.059	.237	.244	.252	.174	-.182	-.236	.198	.346	.264	.403	.368	.410	.421	.441	.433	.475	.356	.361	.266	.408	.142	.173
																			.793	.578	.629	.653	.625	.590	.568	.511	.673	.737	-.053	.143	.265	.364	.322	.275	-.021	-.066	.333	.514	.422	.543	.488	.500	.497	.512	.510	.582	.504	.465	.404	.464	.054	.138
																				.714	.681	.768	.770	.686	.596	.622	.644	.707	-.243	-.071	.464	.520	.475	.447	.133	.085	.340	.472	.420	.518	.505	.538	.557	.536	.495	.612	.506	.506	.459	.560	-.158	-.098
																					.718	.698	.766	.616	.706	.663	.715	.796	-.063	.070	.570	.559	.566	.572	.057	-.007	.357	.546	.509	.575	.570	.604	.609	.610	.548	.615	.582	.534	.506	.612	-.049	.004
																						.739	.731	.528	.622	.605	.630	.729	-.098	.086	.389	.413	.426	.420	-.138	-.113	.393	.490	.406	.515	.555	.556	.492	.518	.463	.560	.508	.463	.414	.525	.053	.142
																							.846	.755	.705	.720	.739	.776	-.253	-.132	.564	.565	.521	.515	-.019	-.036	.412	.510	.442	1564	.578	.562	.571	.605	.601	.615	.568	.513	.505	.613	-.124	-.085
																								.733	.760	.773	.787	.857	-.222	-.084	.515	.585	.564	.591	.053	.033	.288	.528	.490	.566	.558	.582	.560	.635	.600	.674	.653	.582	.529	.661	-.132	-.092
																									.746	.695	.637	.697	-.041	.055	.325	.366	.385	.363	.076	.007	.284	.433	.381	.428	.461	.476	.465	.505	.526	.522	.464	.426	.469	.477	-.081	-.055
																										.800	.838	.828	-.071	.129	.497	.509	.527	.501	.070	-.018	.248	.540	.514	.635	.606	.666	.617	.696	.685	.711	.699	.615	.544	.668	-.012	.058
																											.772	.727	-.174	-.039	.513	.542	.598	.557	.070	-.003	.303	.507	.490	.603	.590	.653	.643	.671	.670	.677	.659	.630	.585	.645	-.047	.009
																												.871	-.003	.091	.463	.522	.519	.452	-.151	-.154	.340	.592	.545	.667	.622	.666	.625	.650	.685	.703	.703	.558	.470	.645	.131	.166
																													-.096	.112	.532	.570	.572	.583	.026	-.015	.386	.644	.581	.688	.689	.694	.653	.737	.695	.761	.767	.731	.613	.732	.009	.085
																														.749	-.355	-.317	-.298	-.412	-.513	-.643	-.265	-.132	-.060	-.043	-.123	-.082	-.154	-.154	-.114	-.159	-.057	-.119	-.155	-.231	.776	.711
																															-.099	-.097	-.084	-.110	-.245	-.385	-.072	.108	.140	.201	.040	.104	.038	.111	.103	.124	.154	.145	.089	.071	.549	.684
																																.900	.865	.877	.278	.224	.502	.532	.524	.647	.663	.673	.757	.712	.698	.720	.703	.705	.719	.790	-.325	-.237
																																	.879	.859	.300	.255	.519	.556	.500	.663	.669	.699	.742	.711	.707	.739	.728	.717	.725	.814	-.303	-.230
																																		.919	.295	.262	.464	.540	.488	.626	.692	.700	.745	.695	.771	.777	.725	.718	.720	.803	-.285	-.210
																																			.416	.390	.437	.544	.527	.623	.675	.668	.709	.710	.712	.741	.710	.721	.719	.800	-.402	-.299
																																				.888	.094	-.002	-.033	-.038	-.057	-.053	.053	.066	-.007	.022	.050	.030	.076	.064	-.710	-.651
																																					.114	-.042	-.136	-.113	-.131	-.130	-.048	-.023	-.112	-.027	-.050	-.053	-.008	.028	-.850	-.797
																																						.764	.620	.594	.675	.573	.654	.561	.525	.557	.452	.535	.612	.540	-.106	-.034
																																							.882	.859	.870	.789	.763	.806	.766	.798	.712	.799	.775	.750	.013	.108
																																								.910	.867	.802	.777	.861	.765	.772	.789	.845	.806	.769	.115	.199
																																									.905	.924	.866	.927	.858	.861	.883	.907	.841	.874	.093	.197
																																										.919	.902	.886	.897	.867	.827	.872	.867	.857	.096	.166
																																											.912	.900	.889	.885	.866	.886	.837	.895	.101	.180
																																												.888	.922	.874	.838	.883	.835	.856	-.002	.075
																																													.888	.920	.920	.926	.883	.919	-.017	.086
																																														.097	.874	.886	.848	.882	.044	.130
																																															.891	.895	.828	.932	-.021	.089
																																																.893	.856	.894	.019	.099
																																																	.896	.896	.028	.139
																																																		.862	-.038	.055
																																																			-.075	.044
																																																				.956

STEPWISE REGRESSION RESULTS FOR SPECIFIC
TERMINAL STEP TEST PARAMETERS TO BALKE
TREADMILL TEST PERFORMANCE TIME

FORMAT:

VARIABLE	CONSTANT BETA WEIGHT	BETA WEIGHT ST'D ERROR	t - SCORE	VARIANCE ACCOUNTED FOR
d.f.	REGRESSION SUM OF SQUARES ERROR SUM OF SQUARES TOTAL SUM OF SQUARES STANDARD ERROR OF ESTIMATE	REGRESSION MEAN SQUARE ERROR MEAN SQUARE	F - RATIO	

	10.845			
Step test perf. time	2.394	0.297	8.07	60.24
1	205.355	205.355	65.16	
43	135.513	3.151		
44	340.868			
	1.775			
	15.901			
Step test perf. time	2.453	0.286	8.57	60.24
St. post-exer. h.r. at 2.5	-0.0452	0.021	-2.14	3.93
2	218.756	109.378	37.62	
42	122.112	2.907		
44	340.868			
	1.705			

STEPWISE REGRESSION RESULTS FOR SPECIFIC
TERMINAL STEP TEST PARAMETERS TO BALKE
TREADMILL TEST PERFORMANCE TIME

	14.412			
Step test perf. time	2.508	0.280	8.95	60.24
St. post-exer. h.r. at 2.5	-0.1009	0.037	-2.75	3.93
St. post-exer. h.r. at 5.5	0.0724	0.039	1.83	2.72
3	228.027	76.009	27.61	
41	112.841	2.752		
44	340.868			
	1.659			
	15.302			
Step test perf. time	2.365	0.289	8.17	60.24
St. post-exer. h.r. at 2.5	-0.0668	0.042	-1.59	3.93
St. post-exer. h.r. at 5.5	0.1239	0.050	2.45	2.72
St. post-exer. h.r. at 7.0	-0.0951	0.060	-1.59	1.98
4	234.780	58.695	22.13	
40	106.088	2.652		
44	340.868			
	1.629			
	15.201			
Step test perf. time	2.320	0.292	7.95	60.24
St. post-exer. h.r. at 2.5	-0.096	0.050	-1.92	3.93
St. post-exer. h.r. at 5.5	0.101	0.055	1.85	2.72
St. post-exer. h.r. at 7.0	-0.107	0.060	-1.76	1.98
St. post-exer. h.r. at 2.0	0.060	0.056	1.07	0.89
5	237.807	47.561	17.99	
39	103.061	2.643		
44	340.868			
	1.626			

STEPWISE REGRESSION RESULTS FOR SPECIFIC
TERMINAL STEP TEST PARAMETERS TO BALKE
TREADMILL TEST PERFORMANCE TIME

	16.863			
Step test perf. time	2.316	0.293	7.91	60.24
St. post-exer. h.r. at 2.5	-0.082	0.053	-1.54	3.93
St. post-exer. h.r. at 5.5	0.102	0.055	1.85	2.72
St. post-exer. h.r. at 7.0	-0.117	0.062	-1.90	1.98
St. post-exer. h.r. at 2.0	0.095	0.069	1.38	0.89
St. post-exer. h.r. at 1.5	-0.051	0.058	-0.88	0.61
6	239.897	39.983	15.04	
38	100.971	(2.657)		
44	340.868			
	(1.630)			

APPENDIX D

RAW SCORES - SAMPLE TWO

SAMPLE TWO

SUBJECT	AGE (yrs.)	WEIGHT (kgs.)	HEIGHT (m)	PERFORMANCE TIME STEP TEST (min.)	PERFORMANCE TIME TREADMILL TEST (min.)
1	18	61.235	1.734	1.05	12.91
2	18	83.462	1.702	1.53	15.19
3	18	75.297	1.816	2.70	19.41
4	20	75.751	1.689	2.19	16.01
5	19	64.864	1.735	3.25	18.11
6	17	64.864	1.702	3.25	20.87
7	18	75.297	1.930	2.89	19.03
8	18	65.318	1.748	2.51	16.70
9	18	63.049	1.930	2.48	16.33
10	20	68.947	1.810	2.75	17.34
11	18	63.049	1.803	1.92	15.50
12	19	73.936	1.816	2.46	16.77
13	18	73.483	1.822	1.73	14.85
14	19	89.812	1.905	2.91	19.82
15	20	76.204	1.829	4.89	19.86
16	18	74.844	1.854	5.14	20.85
17	18	69.400	1.854	2.10	15.41
18	18	78.926	1.854	1.93	15.37
19	18	59.875	1.676	2.08	14.61
20	19	69.854	1.727	1.06	13.29
21	18	63.504	1.676	1.84	16.53
22	19	73.483	1.702	0.78	13.17
23	19	71.668	1.753	1.36	15.01
24	19	68.947	1.753	0.44	11.02
25	20	80.287	1.765	1.69	14.80
26	19	70.761	1.816	1.98	17.03
27	21	73.936	1.727	4.23	19.45
28	18	68.947	1.778	2.14	15.59
29	20	72.576	1.867	1.84	16.11
30	18	68.947	1.854	2.83	18.44

SAMPLE TWO

SUBJECT	AGE (yrs.)	WEIGHT (kgs.)	HEIGHT (m)	PERFORMANCE TIME STEP TEST (min.)	PERFORMANCE TIME TREADMILL TEST (min.)
31	19	68.039	1.727	3.57	20.27
32	19	65.318	1.689	1.44	15.30
33	18	67.132	1.861	0.58	14.35
34	17	68.947	1.753	1.51	13.44
35	19	71.215	1.803	3.44	20.16
36	19	63.957	1.714	1.51	15.05
37	19	69.854	1.797	3.21	18.52
38	19	73.709	1.829	1.81	16.67
39	18	66.679	1.829	2.73	18.75
40	18	79.833	1.848	4.18	20.30
41	19	78.926	1.746	2.87	16.70
42	18	72.122	1.721	2.16	14.61
43	18	71.215	1.746	1.83	16.40
44	18	56.246	1.632	1.28	12.70
45	17	61.009	1.695	2.14	16.67

SAMPLE TWO
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
1	112 110 113 112	175 180 155 141 133 130 122 115 114 114 118 115 113 118 113 112
2	94 112 124 104	160 173 173 180 155 134 133 122 120 118 114 113 112 109 109 112 112 105
3	92 103 103 99	155 160 173 173 177 180 155 142 133 125 120 117 118 118 114 116 114 117 115 114
4	90 78 100 103	149 160 173 173 180 155 144 133 124 117 122 117 115 100 112 110 109 113 110
5	70 70 69 69	140 149 160 170 175 180 155 138 127 112 107 98 96 98 92 96 94 90 92 89
6	98 96 91 87	155 166 169 169 173 173 180 142 122 118 112 114 114 103 112 100 105 99 103 107 97
7	87 83 96 85	147 160 166 173 177 180 144 133 109 105 113 104 100 100 100 100 97 96 97 96
8	84 82 83 88	147 157 169 177 180 155 135 128 120 118 104 112 112 100 92 100 103 100 101
9	90 92 91 86	140 153 166 173 180 162 140 137 128 127 117 124 117 114 122 118 109 114 105
10	117 114 112 113	155 157 163 170 175 180 166 160 152 147 142 130 130 130 130 135 137 140 133 130

SAMPLE TWO
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
11	77 81 87 106	155 169 173 180 149 130 130 127 122 115 109 113 103 94 118 114 101 110
12	67 78 77 76	163 169 173 173 180 160 140 130 122 118 114 112 110 109 109 112 113 102 99
13	88 83 89 91	150 173 175 180 159 150 141 124 122 125 115 125 110 119 114 106 117 115
14	63 61 59 73	147 157 165 173 177 180 149 135 113 115 104 94 97 92 95 95 78 87 94 84
15	100 74 93 79	140 155 163 166 166 170 170 173 173 180 163 142 120 128 124 120 118 113 120 114 118 118 116 113
16	54 59 61 71	133 144 149 158 160 160 168 169 177 177 180 149 133 122 112 109 109 100 100 97 93 94 95 100 96
17	98 82 69 79	155 157 169 180 150 132 118 122 110 104 103 118 115 107 96 97 101 98
18	112 98 100 112	167 170 174 180 161 151 129 123 119 117 112 112 111 106 110 110 110 107
19	97 94 90 98	146 165 167 177 180 150 134 128 123 113 123 112 119 111 107 110 111 115 112
20	80 88 85 87	173 180 153 132 126 119 105 103 112 100 101 100 111 100 105 98

SAMPLE TWO
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
21	90 102 100 102	153 163 173 180 153 143 132 122 122 116 116 111 112 112 110 111 111 108
22	85 97 90 101	173 180 150 134 117 117 107 109 119 109 109 119 105 112 116 112
23	79 115 87 103	158 173 180 161 153 136 138 132 125 124 125 115 123 120 120 120 120
24	87 88 91 85	180 125 100 102 96 70 65 80 79 90 64 84 88 95 82
25	87 73 78 80	156 159 175 180 161 150 139 128 119 113 110 113 112 112 109 108 103 102
26	70 79 84 80	158 169 180 140 113 98 100 99 89 98 93 93 88 94 99 90 89
27	62 67 58 57	125 145 153 166 167 173 177 177 180 154 145 128 128 119 111 113 104 101 105 102 100 95 92
28	100 107 93 99	162 169 173 180 159 134 125 120 113 117 110 115 110 110 106 106 105 102
29	112 116 105 103	163 167 174 180 158 158 131 123 112 114 120 117 117 113 111 122 117 116
30	90 77 77 85	138 153 163 167 175 180 156 141 125 111 115 113 103 99 94 101 102 103 103 102

SAMPLE TWO
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
31	74 96 111 76	163 167 167 173 173 177 180 141 141 128 122 126 117
		117 113 119 106 109 103 109 110
32	79 71 78 70	156 174 180 136 130 122 113 109 97 98 95 105 92
		97 98 90 88
33	133 129 125 128	180 163 150 141 145 134 138 138 132 138 136 136 134
		138 132
34	93 88 81 86	169 173 180 158 138 129 128 119 124 113 111 111 111
		119 115 110 113
35	78 76 87 81	136 151 159 167 173 177 180 153 131 122 115 111 111
		112 108 110 107 102 96 106 101
36	100 119 120 108	161 174 180 167 156 135 128 123 123 122 123 117 115
		117 117 127 117
37	105 91 89 90	143 156 167 170 176 178 180 161 148 138 134 128 130
		125 122 125 122 117 122 122 115
38	83 80 81 79	153 169 175 180 165 159 141 134 136 130 120 124 112
		123 109 119 115 115
39	90 89 91 86	150 163 173 173 180 163 145 130 120 117 118 105 105
		120 117 112 107 113 115 110
40	70 76 70 80	134 150 159 159 165 169 173 177 180 156 143 123 126
		116 119 113 111 103 106 106 103 110 101

SAMPLE TWO
STEP TEST HEART RATES
(Beats/min. recorded every 30 seconds)

SUBJECT	PRE-EXERCISE	EXERCISE AND POST-EXERCISE
41	69 65 70 82	142 162 167 173 177 180 161 129 125 113 102 99 103 105 101 98 101 94 100 95
42	99 106 102 80	147 163 171 176 180 156 145 131 121 126 123 121 115 113 112 115 117 111 111
43	78 86 83 94	159 168 175 180 128 112 114 99 116 111 103 104 101 106 100 99 99 108
44	94 100 93 94	177 180 166 130 130 114 120 112 112 98 99 99 102 109 102 104
45	90 83 85 87	155 173 177 177 180 140 127 112 114 110 100 99 99 100 100 94 96 98 96

SAMPLE TWO
TREADMILL TEST HEART RATES
(Beats/min. recorded every minute)

SUBJECT	EXERCISE
1	152 133 144 155 155 155 155 163 168 173 173 173 180
2	125 127 128 117 137 138 155 156 160 163 165 166 173 177 177 180
3	105 110 114 114 114 118 124 120 130 134 135 142 140 149 155 160 166 169 173 180
4	103 101 112 113 117 124 133 142 146 148 155 160 163 173 173 180
5	117 110 114 122 117 120 120 126 130 135 140 144 152 160 168 169 173 180
6	113 95 105 103 103 112 113 117 122 126 127 135 135 144 149 144 160 162 169 173 180
7	110 103 112 111 114 120 120 135 134 137 142 144 152 155 160 169 169 173 173 180
8	110 107 114 103 112 114 127 127 127 141 142 152 156 163 167 173 180
9	117 114 112 117 122 125 130 130 135 147 152 156 160 166 173 177 180
10	119 117 120 123 130 132 134 134 142 147 156 158 162 167 170 175 178 180

SAMPLE TWO
TREADMILL TEST HEART RATES
(Beats/min. recorded every minute)

SUBJECT	EXERCISE
11	112 119 123 125 128 133 136 143 147 149 150 161 167 170 177 180
12	124 122 123 127 127 131 135 140 142 149 152 160 163 166 169 173 180
13	113 110 109 128 126 123 132 134 139 138 156 158 167 173 180
14	97 96 100 99 100 114 114 114 117 119 127 130 140 144 153 158 162 168 174 180
15	120 120 122 128 127 128 133 138 142 144 155 155 157 162 166 169 171 175 177 180
16	122 120 123 119 123 126 128 128 130 132 136 140 153 156 167 167 170 172 175 177 180
17	132 130 125 130 129 136 134 140 144 156 161 167 169 175 179 180
18	136 141 143 141 140 145 145 150 158 159 163 168 171 176 179 180
19	120 122 119 122 124 128 136 141 147 152 159 163 169 175 180
20	128 120 117 119 125 127 130 136 143 156 162 173 175 180

SAMPLE TWO
TREADMILL TEST HEART RATES
(Beats/min. recorded every minute)

SUBJECT	EXERCISE
21	130 128 126 126 130 124 128 134 141 139 143 149 157 164 170 173 180
22	128 120 124 127 125 139 139 143 148 153 164 167 175 180
23	105 109 109 111 115 119 123 129 132 135 145 156 164 170 180
24	120 120 120 119 130 125 150 145 156 173 180
25	127 126 126 126 130 134 136 145 148 153 161 164 173 173 180
26	115 115 111 124 119 125 122 127 130 141 143 151 158 164 171 175 177 180
27	109 99 103 94 101 107 109 113 114 128 126 136 142 143 154 167 167 174 178 180
28	145 141 136 134 141 143 147 151 156 161 163 167 170 175 178 180
29	134 134 130 136 138 136 141 143 145 148 153 156 159 164 167 177 180
30	113 110 117 120 115 122 122 128 132 136 141 143 147 156 161 167 173 176 180

SAMPLE TWO
TREADMILL TEST HEART RATES
(Beats/min. recorded every minute)

SUBJECT	EXERCISE
31	111 106 101 109 113 118 119 119 127 130 130 134 143 145 153 156 163 170 174 174 180
32	112 106 113 112 113 122 123 127 128 136 149 147 159 161 173 180
33	141 141 139 136 141 145 150 154 156 156 161 167 169 175 180
34	130 136 141 141 147 147 150 158 159 164 167 173 176 180
35	106 100 101 98 99 107 105 107 113 119 126 132 135 143 145 156 166 170 175 177 180
36	126 128 125 130 131 130 137 139 145 153 158 164 167 173 180
37	117 118 117 122 121 125 124 130 134 141 139 143 147 154 159 164 170 177 180
38	108 111 110 114 119 123 122 128 130 141 145 150 161 161 170 173 180
39	107 111 115 120 120 124 130 130 134 136 145 150 155 159 159 167 172 177 180
40	123 117 122 113 126 125 128 131 134 138 142 147 150 156 159 161 164 167 173 178 180

SAMPLE TWO
TREADMILL TEST HEART RATES
(Beats/min. recorded every minute)

SUBJECT	EXERCISE
41	108 98 107 106 111 113 120 115 121 130 139 145 156 162 166 173 180
42	138 140 143 145 148 150 156 162 161 162 167 170 173 177 180
43	116 113 115 110 120 118 110 115 129 129 137 143 157 168 168 178 180
44	118 125 128 128 130 135 144 155 159 163 170 172 180
45	109 124 117 124 125 130 135 135 140 142 147 152 157 163 169 177 180

OBSERVED AND PREDICTED TREADMILL TEST
PERFORMANCE TIMES (Min.) FOR SAMPLE TWO

SUBJECT	OBSERVED	PREDICTED			
		Y_1	Y_2	Y_3	Y_4
1	12.91	13.36	12.96	12.92	12.99
2	15.19	14.51	14.23	14.03	14.42
3	19.41	17.31	17.10	17.33	16.95
4	16.01	16.09	15.98	16.06	15.83
5	18.11	18.62	19.04	18.57	19.00
6	20.87	18.62	18.72	18.23	18.41
7	19.03	17.76	17.88	17.28	17.48
8	16.70	16.85	16.72	16.04	16.15
9	16.33	16.78	16.24	16.36	17.32
10	17.34	17.43	16.23	16.90	16.93
11	15.50	15.46	15.12	15.48	15.89
12	16.77	16.73	16.60	16.78	17.70
13	14.85	14.99	14.63	14.70	14.43
14	19.82	17.81	18.34	16.86	16.91
15	19.86	22.55	22.29	22.71	22.36
16	20.85	23.15	23.58	23.11	22.69
17	15.41	15.87	16.08	15.53	15.49
18	15.37	15.46	15.26	15.21	15.37
19	14.61	15.82	15.89	16.19	15.65
20	13.29	13.38	13.75	14.51	15.23
21	16.53	15.25	14.90	14.68	14.86
22	13.17	12.71	12.98	13.17	12.36
23	15.01	14.10	13.27	13.19	13.14
24	11.02	11.89	13.82	14.53	14.28
25	14.80	14.89	14.69	14.54	15.16
26	17.03	15.59	16.28	16.19	16.55
27	19.45	20.97	20.90	20.40	21.25
28	15.59	15.97	16.04	16.05	16.25
29	16.11	15.25	15.35	15.76	14.89
30	18.44	17.62	17.64	17.29	17.25

OBSERVED AND PREDICTED TREADMILL TEST
PERFORMANCE TIMES (Min.) FOR SAMPLE TWO

SUBJECT	OBSERVED	PREDICTED Y_1	Y_2	Y_3	Y_4
31	20.27	19.39	18.96	18.55	18.37
32	15.30	14.29	14.51	14.05	15.08
33	14.35	12.23	11.27	12.19	12.02
34	13.44	14.46	14.23	14.81	14.92
35	20.16	19.08	19.32	19.22	19.06
36	15.05	14.46	14.04	14.26	14.04
37	18.52	18.53	17.99	18.02	17.90
38	16.67	15.18	14.19	13.12	13.08
39	18.75	17.38	17.31	17.20	16.74
40	20.30	20.85	20.91	20.87	20.97
41	16.70	17.72	18.33	18.63	18.75
42	14.61	16.02	15.50	15.44	15.69
43	16.40	15.23	15.15	14.54	14.00
44	12.70	13.91	13.62	12.90	13.06
45	16.67	15.97	16.18	15.49	15.53

Where:
$$Y_1 = 2.394\ X_{76} + 10.845$$
$$Y_2 = 2.453\ X_{76} - 0.0452\ X_{66} + 15.901$$
$$Y_3 = 2.508\ X_{76} - 0.1009\ X_{66} + 0.0724\ X_{72} + 14.412$$
$$Y_4 = 2.365\ X_{76} - 0.0668\ X_{66} + 0.1239\ X_{72} - 0.0951\ X_{75} + 15.302$$

and:
X_{76} = Step Test Performance Time (min.)
X_{66} = Step Test Post-Exercise Heart Rate at 2.5 Min. (beats/min.)
X_{72} = Step Test Post-Exercise Heart Rate at 5.5 Min. (beats/min.)
X_{75} = Step Test Post-Exercise Heart Rate at 7.0 Min. (beats/min.)

APPENDIX E

HEART RATE CALIBRATION

CHART

HEART RATES

Three beat complex - heart rate $= \dfrac{\text{paper speed} \times 60 \times 3}{\text{number of mm.}}$

Paper speed = mm/sec.

24	=	180 beats/min.
25	=	173
26	=	166
27	=	160
28	=	154
29	=	149
30	=	144
31	=	139
32	=	135
33	=	131
34	=	127
35	=	123
36	=	120
37	=	117
38	=	114
39	=	111
40	=	108
41	=	105
42	=	103
43	=	100
44	=	98
45	=	96
46	=	94
47	=	92
48	=	90
49	=	88
50	=	86
51	=	85
52	=	83
53	=	82
54	=	80
55	=	79
56	=	77
57	=	76
58	=	74
59	=	73
60	=	72
61	=	71
62	=	70
63	=	69
64	=	68
65	=	67
66	=	66
67	=	65
68	=	64
69	=	63
70	=	62

Paper speed = 25 mm/sec.

25	=	180 beats/min.
26	=	173
27	=	167
28	=	161
29	=	156
30	=	150
31	=	145
32	=	141
33	=	136
34	=	132
35	=	128
36	=	125
37	=	122
38	=	119
39	=	115
40	=	112
41	=	110
42	=	107
43	=	105
44	=	102
45	=	100
46	=	98
47	=	96
48	=	94
49	=	92
50	=	90
51	=	88
52	=	87
53	=	85
54	=	83
55	=	82
56	=	80
57	=	79
58	=	78
59	=	76
60	=	75
61	=	74
62	=	73
63	=	71
64	=	70
65	=	69
66	=	68
67	=	67
68	=	66
69	=	65
70	=	64
71	=	63